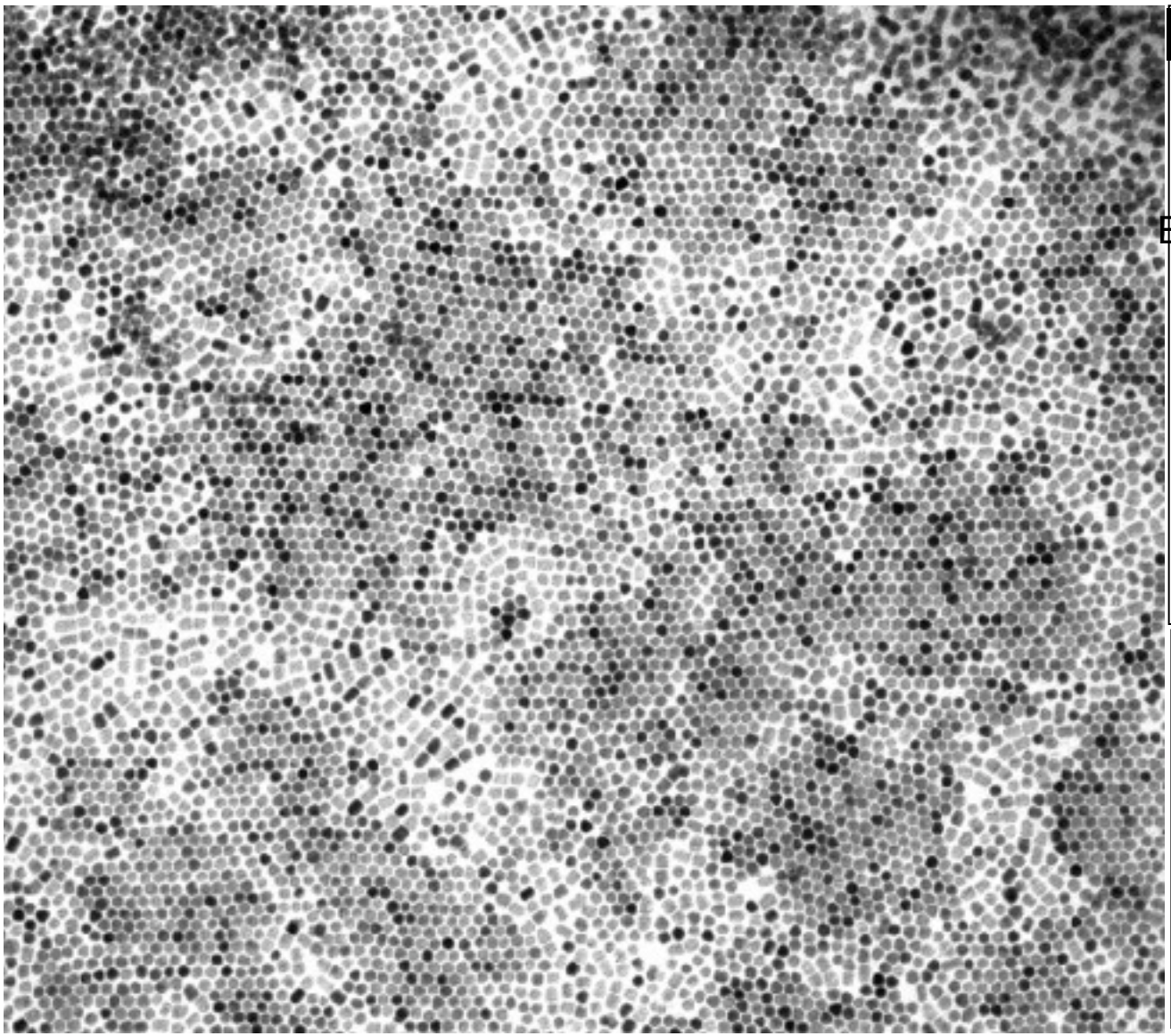
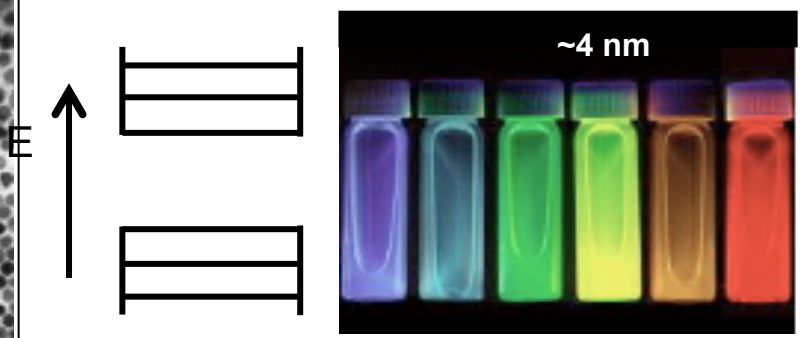
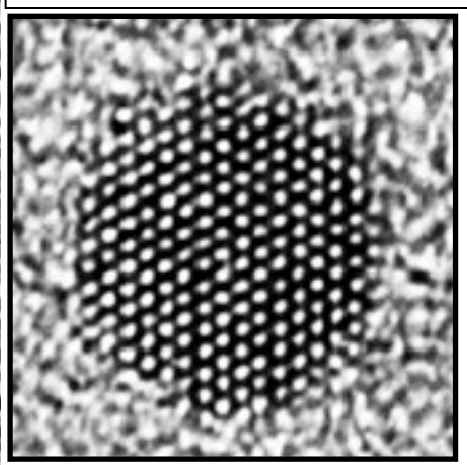
Artificial atom concept and its impact in the chemistry of materials



CdSe nanocrystal as quantum dot



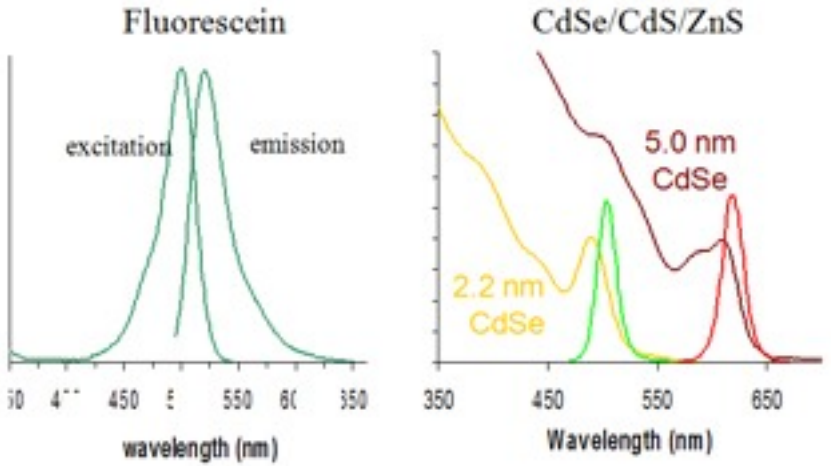
$$E_n = \frac{h^2 n^2}{8ma^2}$$

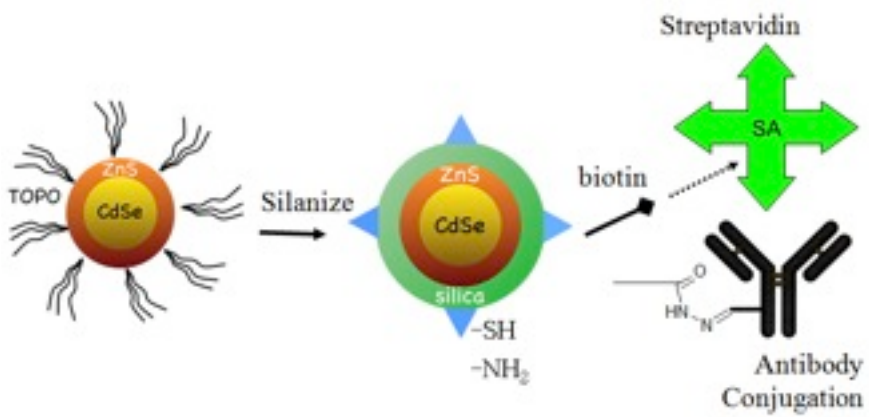


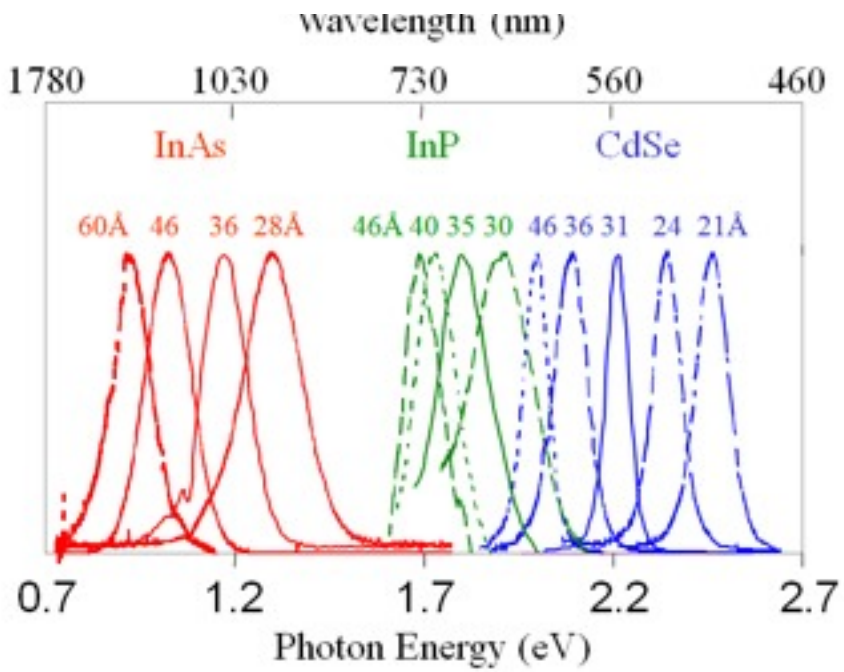
… many scaling laws for size-dependent properties:

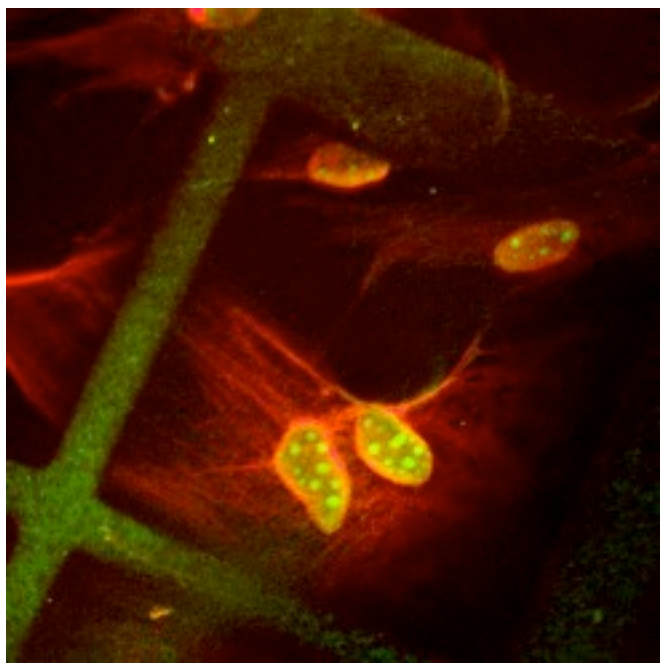
band gap, melting temperature, charging energy…

Quantum Dot Labeling for Biological Imaging









Bruchez, M.; Moronne, M.; Gin, P.; Weiss, S.; Alivisatos, A. P., *Science* **1998**, *281*, 2013-2016.

Chan, W. C. W.; Nie, S. M., Science **1998**, *281*, 2016-2018.

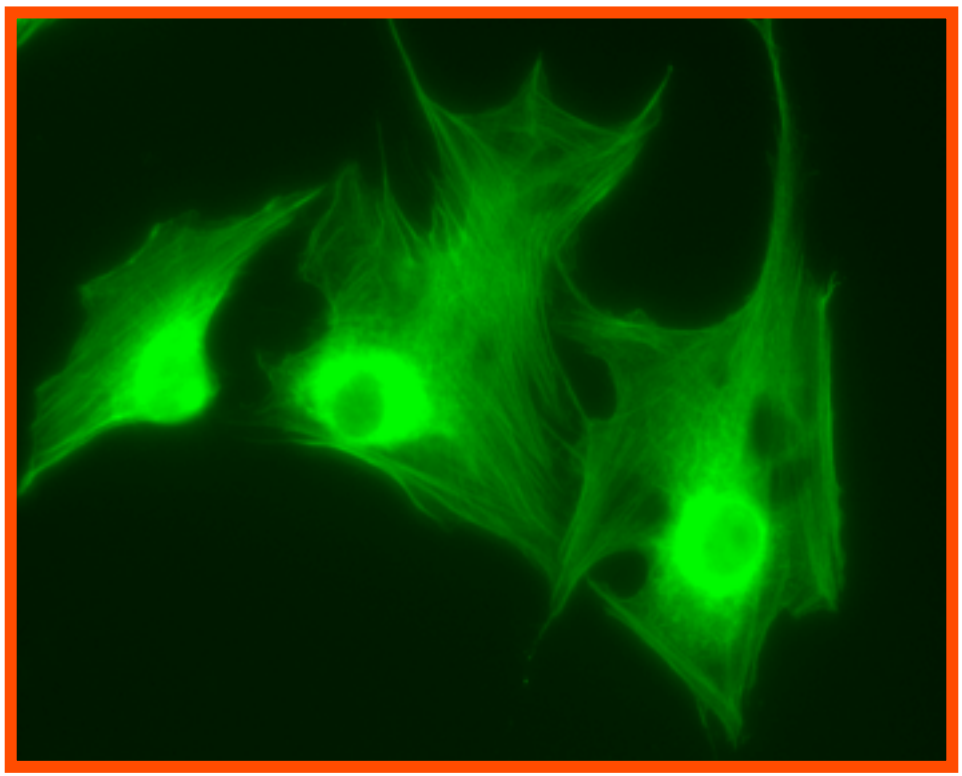
Photostability Comparison

Alexa 488 **Green QDs**

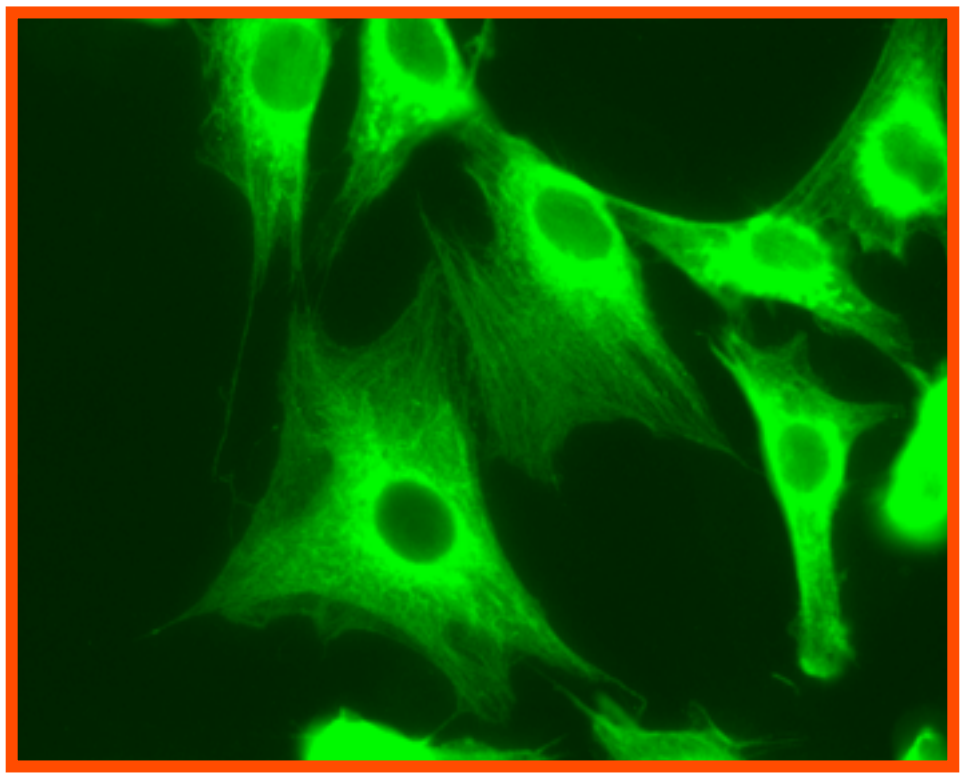
Courtesy Quantum Dot Corporation, now Invitrogen

Photostability Comparison

Alexa 488



Green QDs



Courtesy Quantum Dot Corporation, now Invitrogen

Photostability Comparison

Alexa 488

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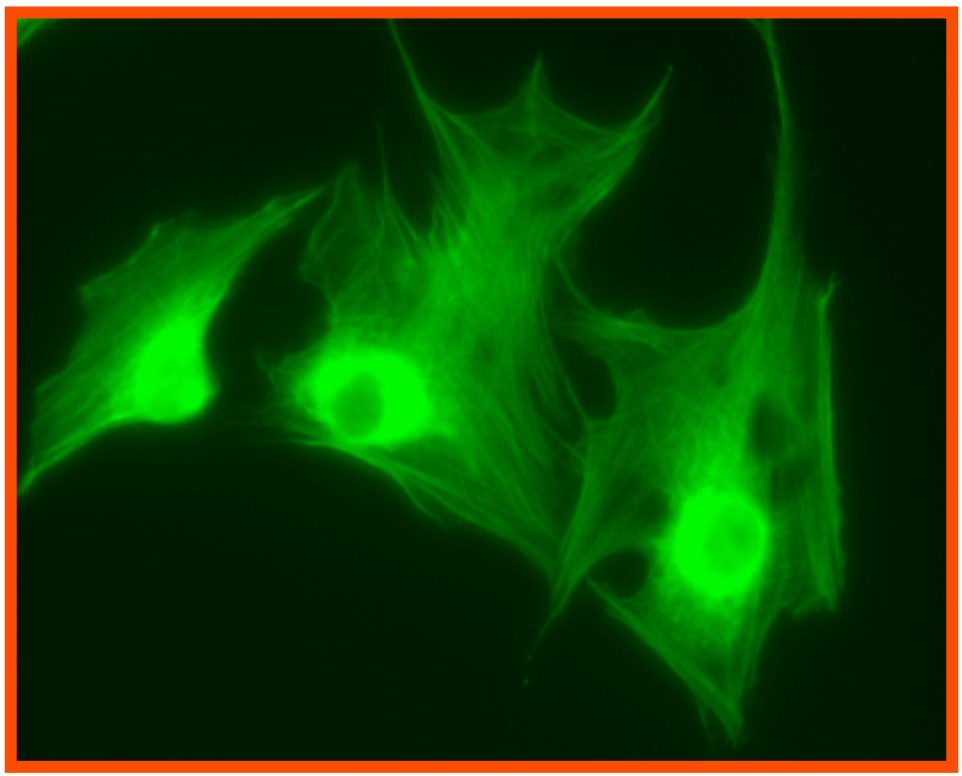

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Photostability Comparison

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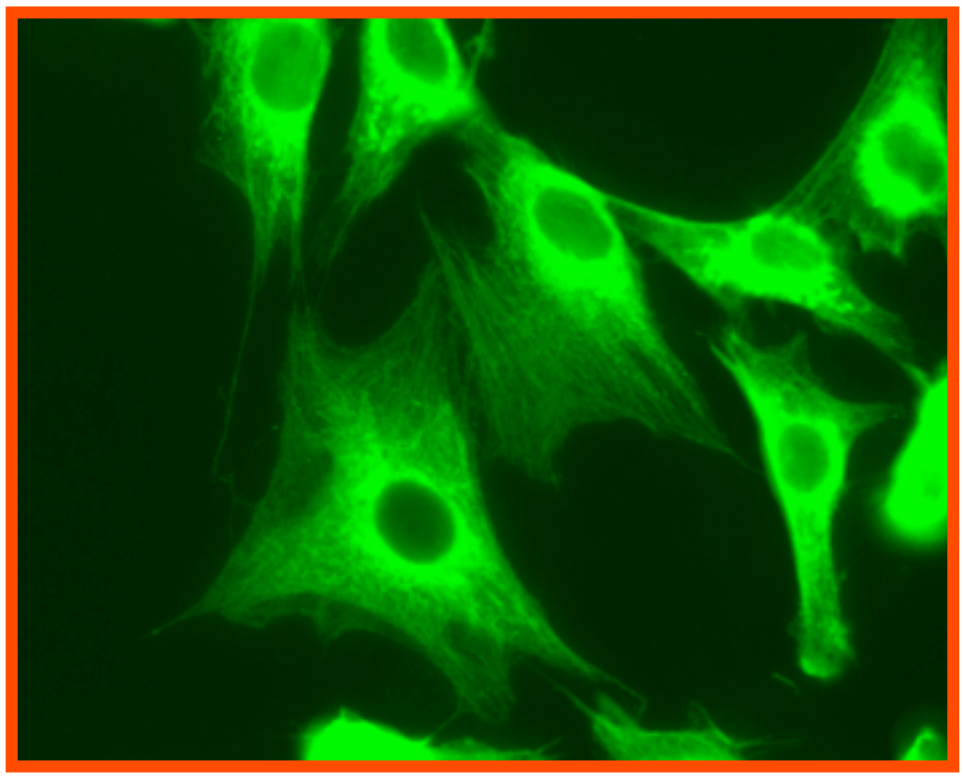
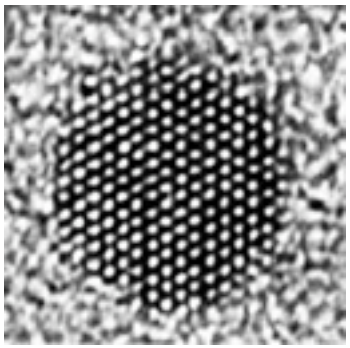
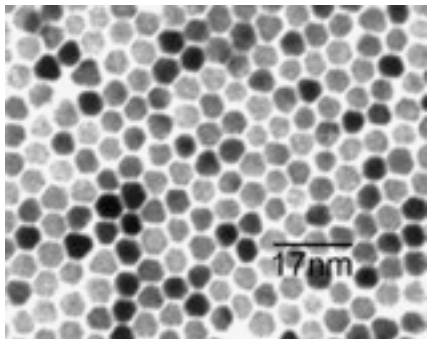
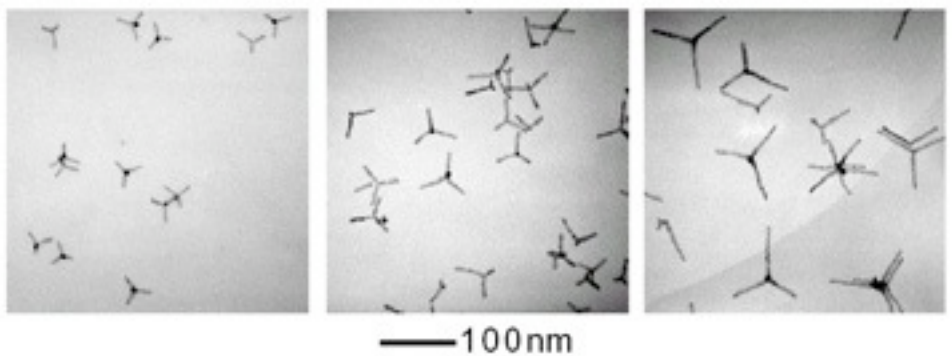


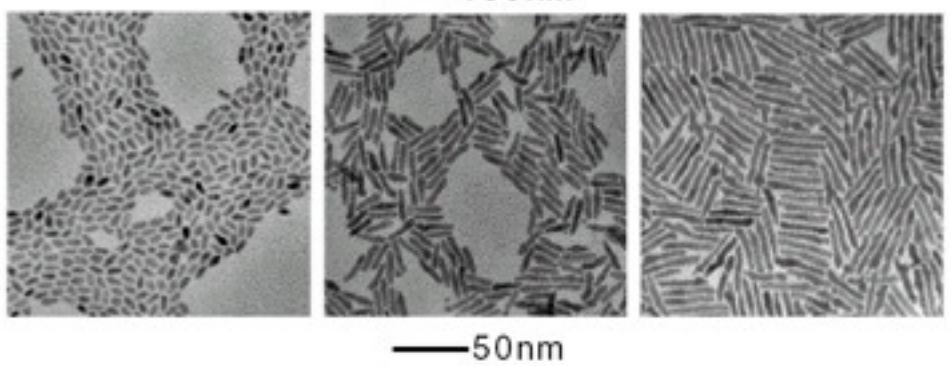
Courtesy Quantum Dot Corporation, now Invitrogen

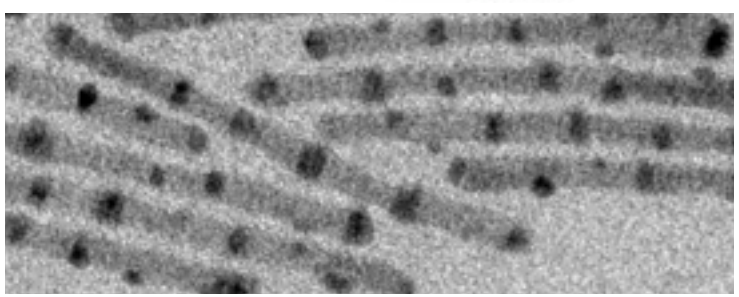
Complexity of shape and composition in colloidal inorganic nanocrystals
Symmetry, topology, connectivity, directionality…

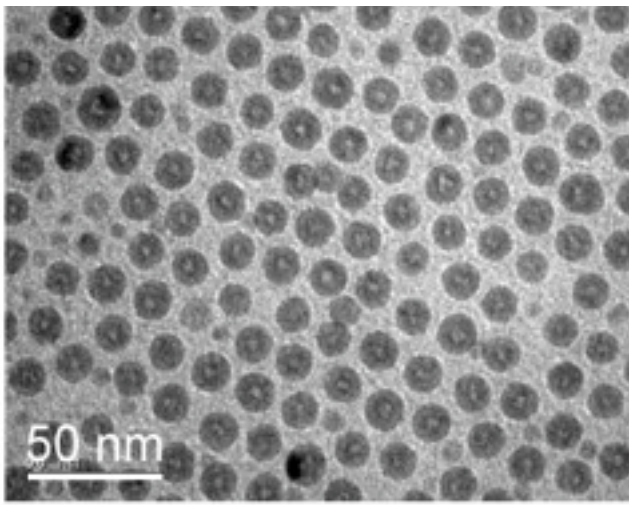


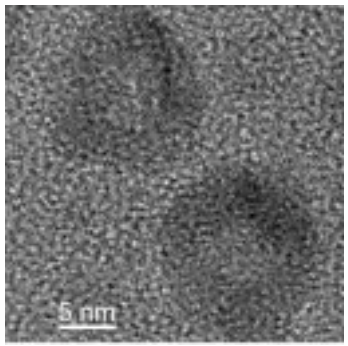


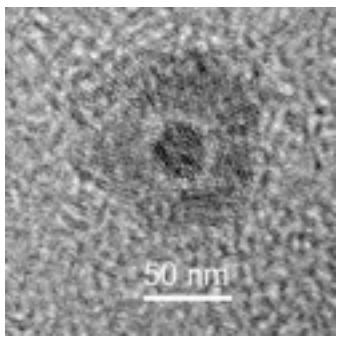


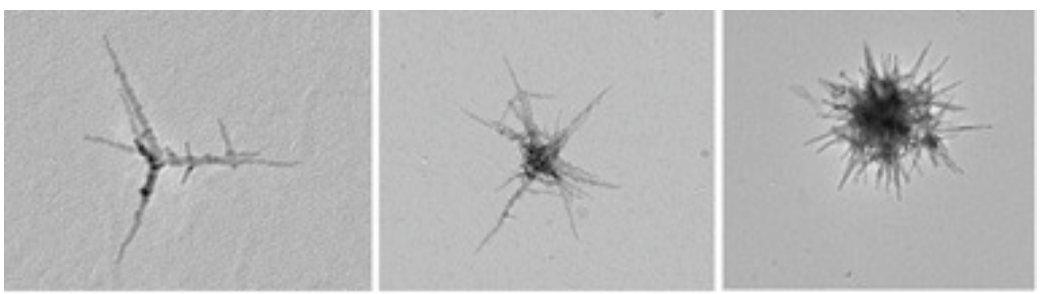


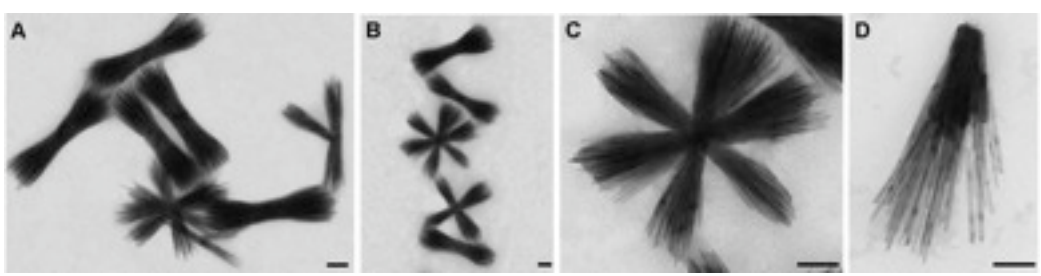












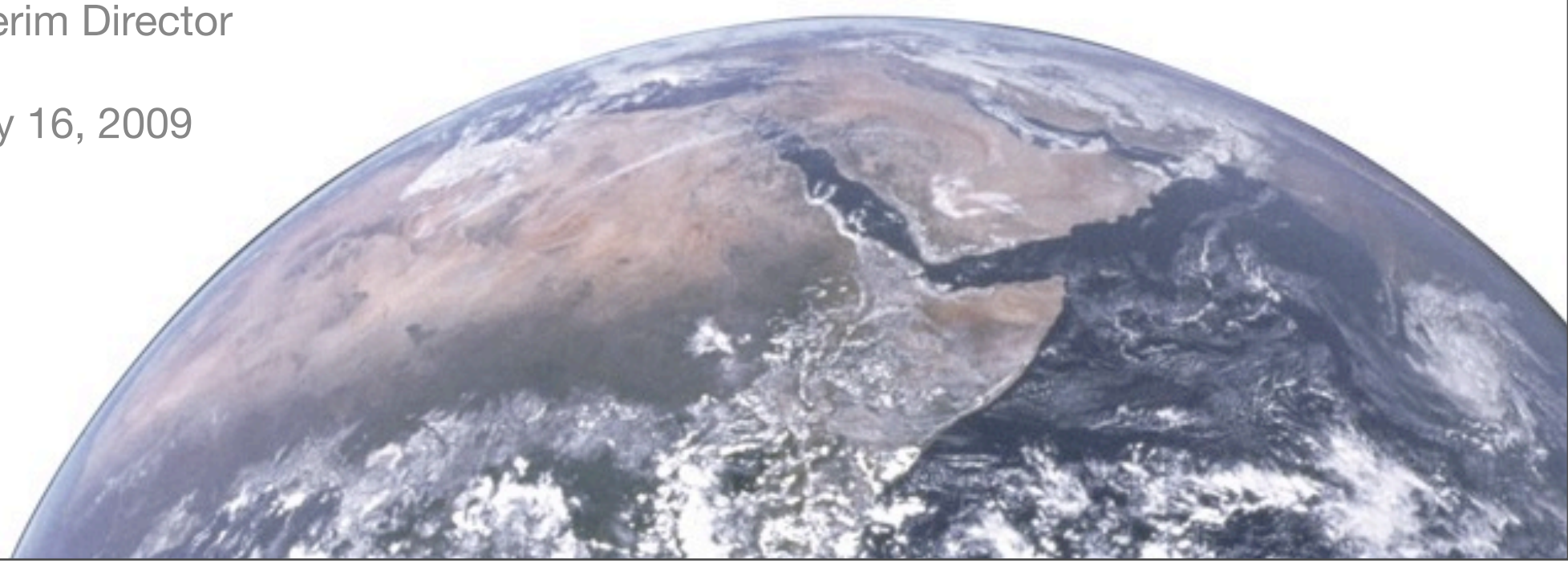
Nanocrystal Molecules made inorganically

ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

The National Lab with a Global Mission

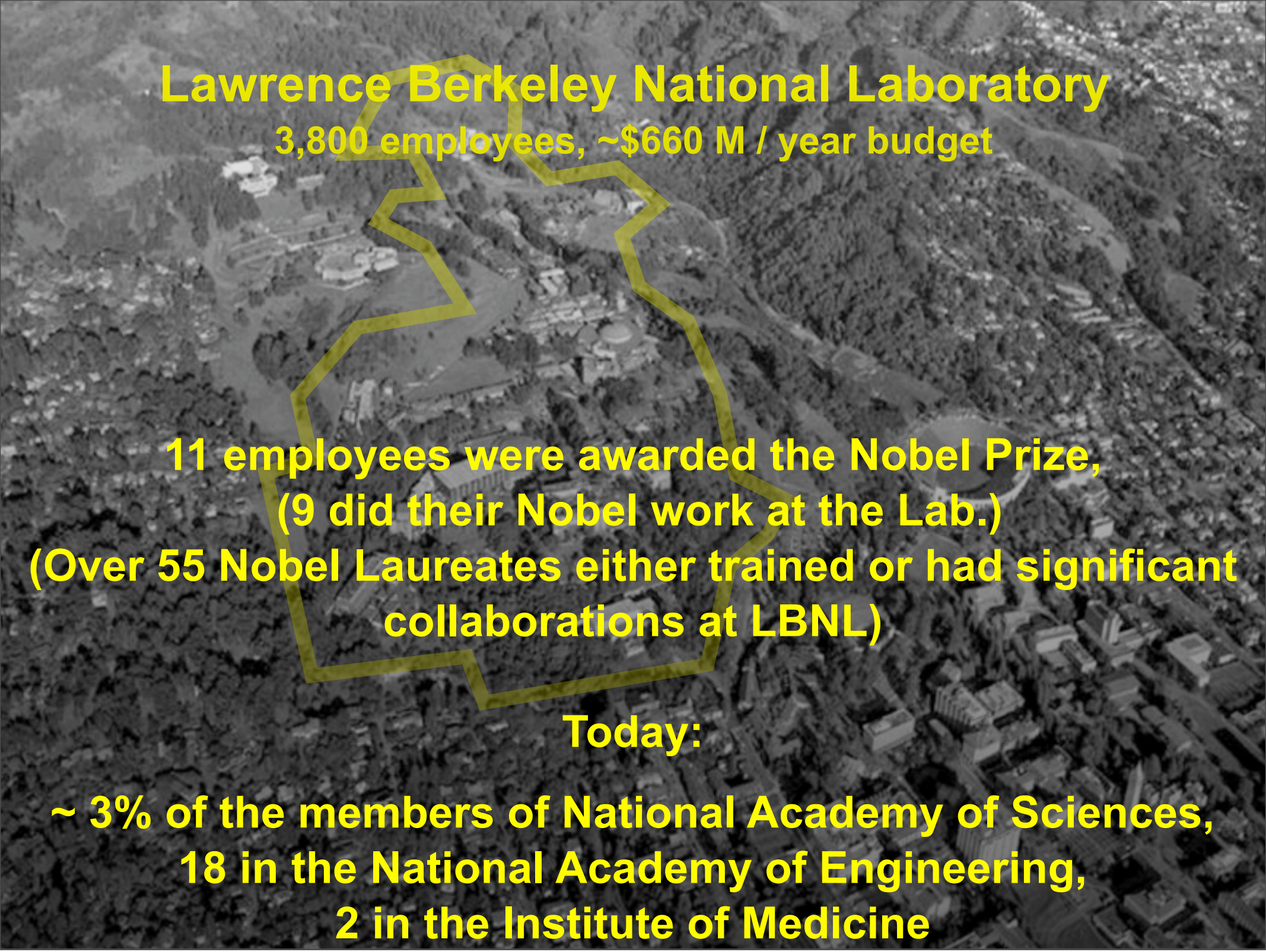
Paul Alivisatos
Interim Director

July 16, 2009

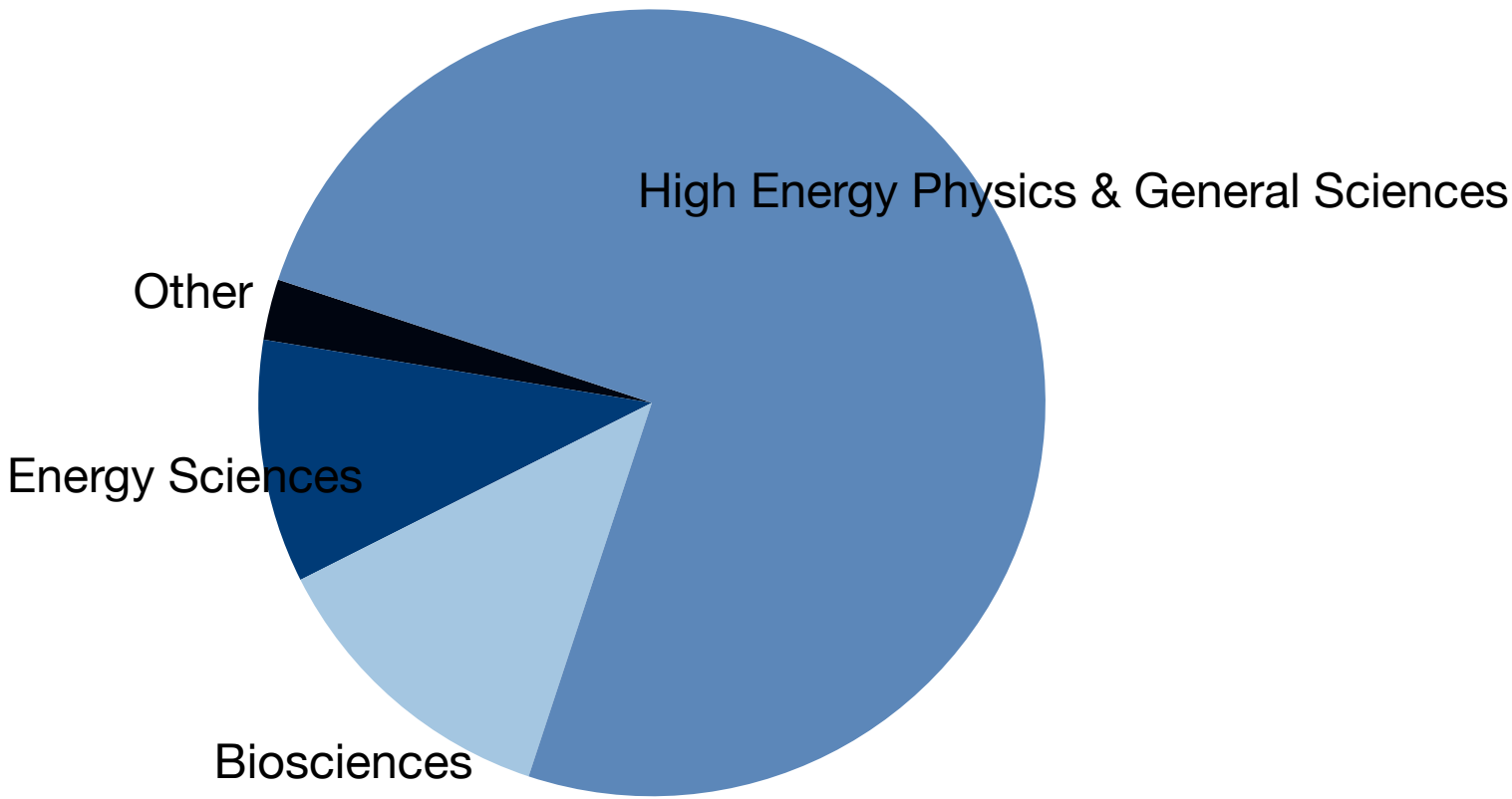



Lawrence introduces
big team science 1931
LBNL the oldest
DOE National Lab

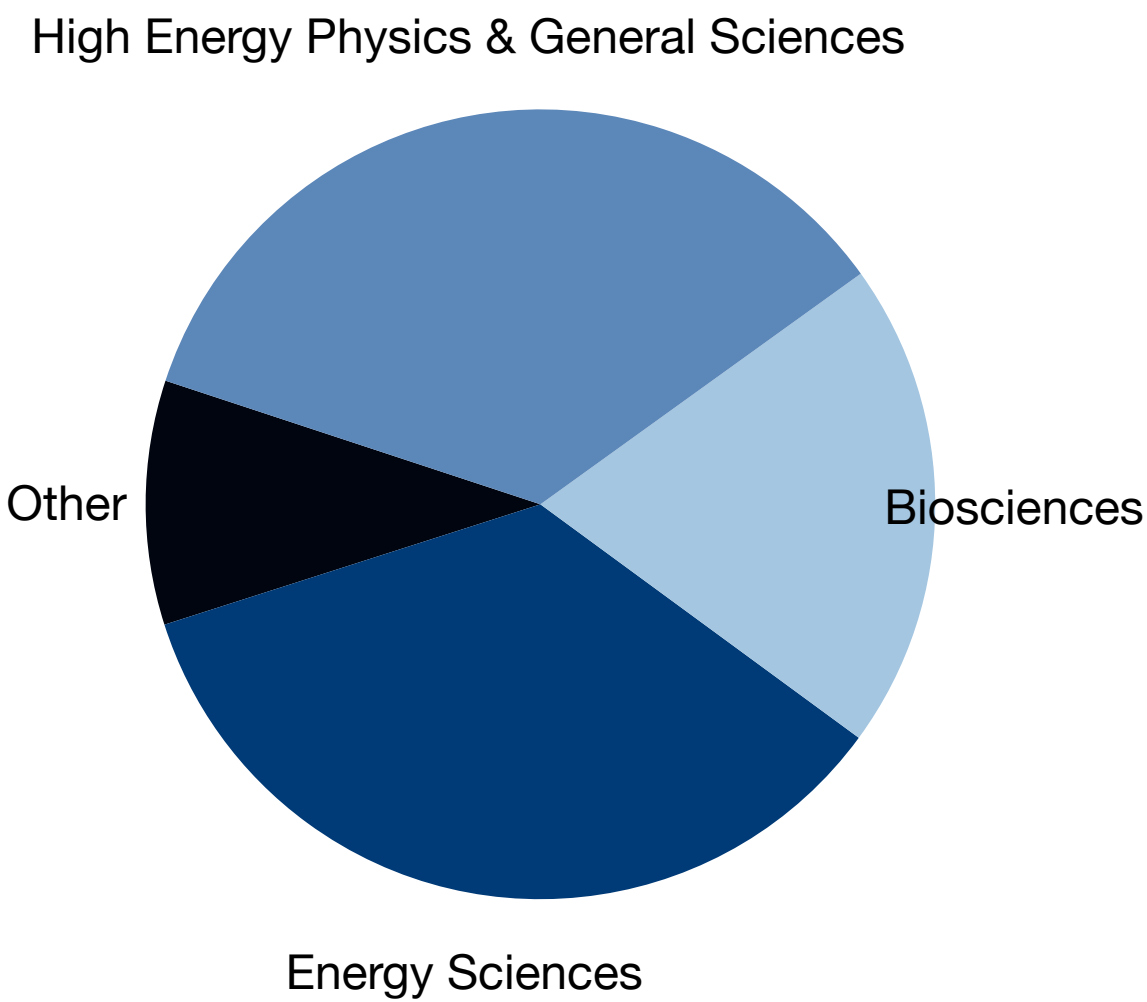

Lawrence Berkeley National Laboratory
3,800 employees, ~$660 M / year budget


Lawrence Berkeley National Laboratory
3,800 employees, ~$660 M / year budget
11 employees were awarded the Nobel Prize,
(9 did their Nobel work at the Lab.)
(Over 55 Nobel Laureates either trained or had significant collaborations at LBNL)
Today:
~ 3% of the members of National Academy of Sciences,
18 in the National Academy of Engineering,
2 in the Institute of Medicine

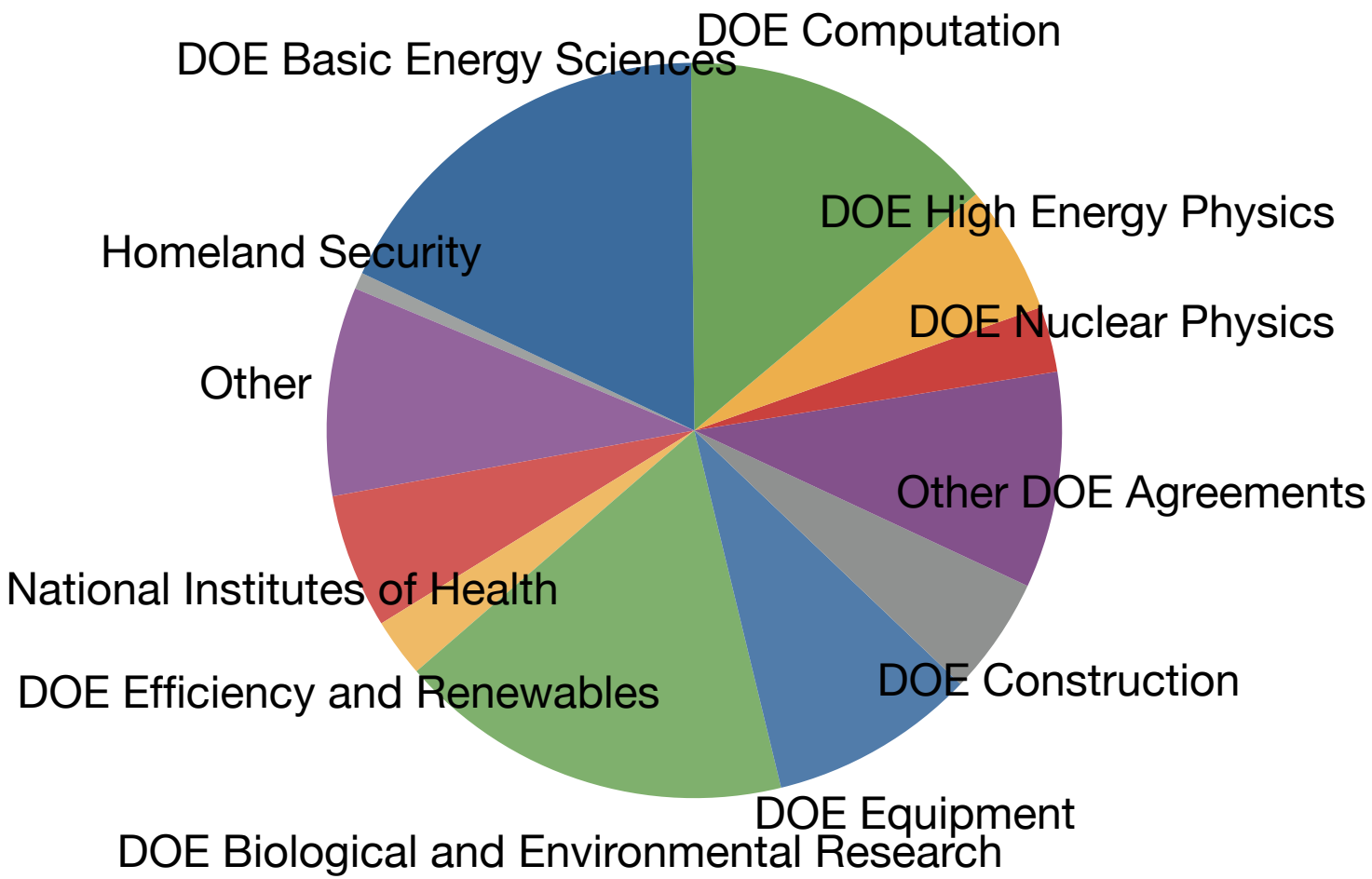
Evolution of the Berkeley Lab Budget: 1970s



Evolution of the Berkeley Lab Budget: 1990s



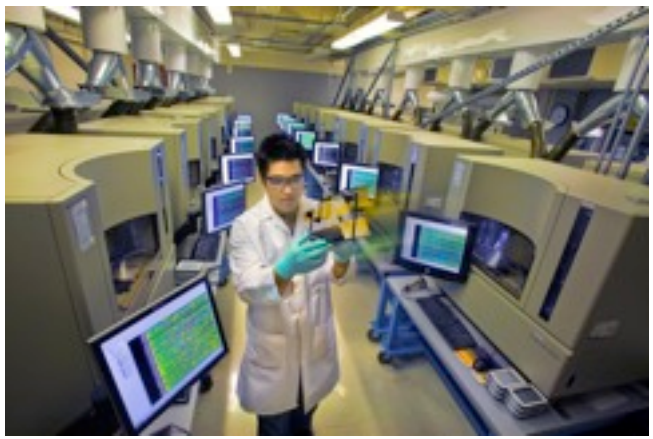
Evolution of the Berkeley Lab Budget: Today



Berkeley Lab Today

- **Engage the lab on the greatest scientific and technical challenges of our times**
- **Foster and harness the creativity of outstanding individuals**
- **Work collectively across disciplines and boundaries to find solutions**
- **Create and share unique tools for science**
- **Create innovative public-private partnerships to solve intractable problems**
- **This is the “Berkeley style” that created LBNL and put UCB on the world science map**

World-Class User Facilities and Research Institutes Underpin our Energy and Environment Programs



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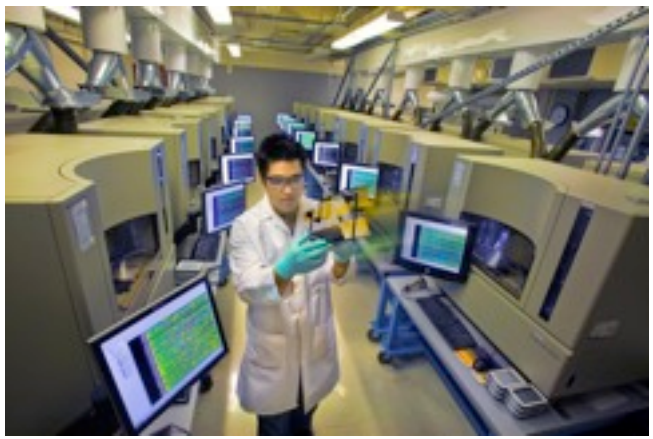

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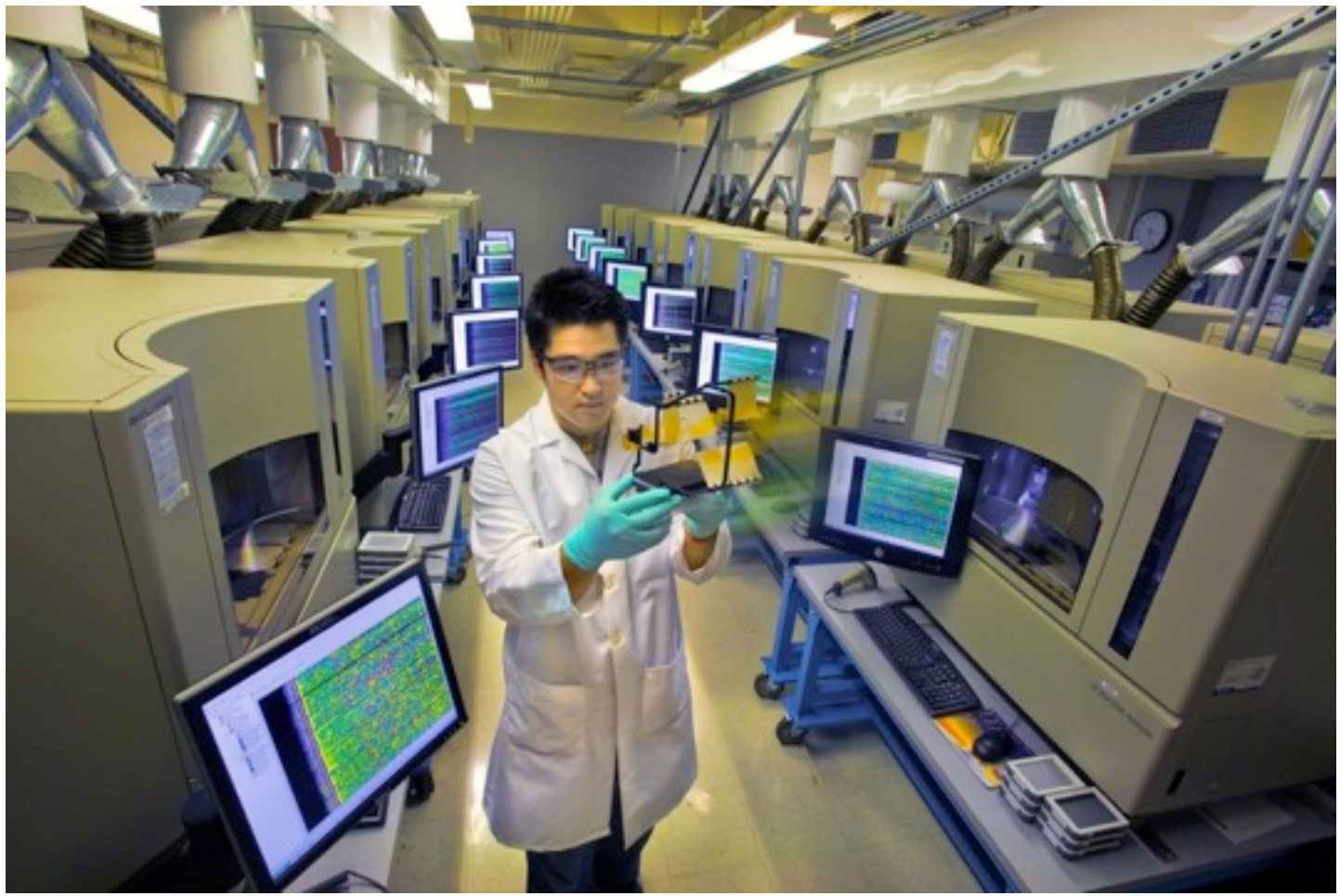

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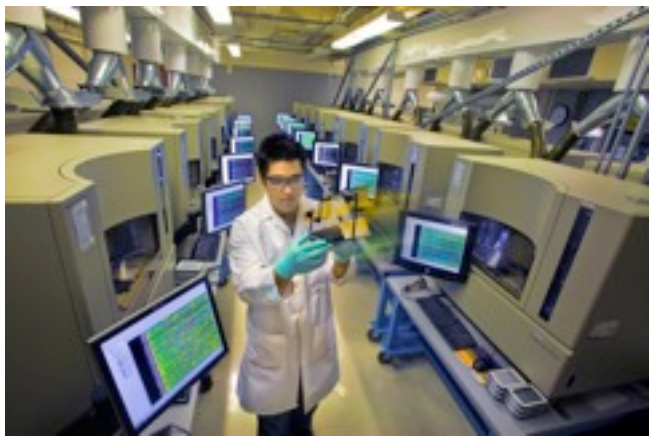

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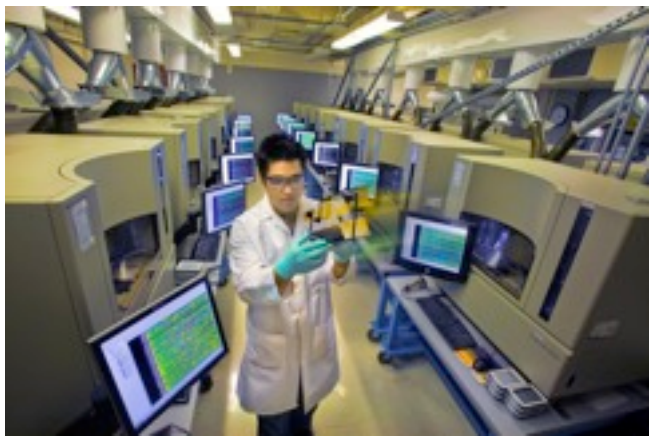

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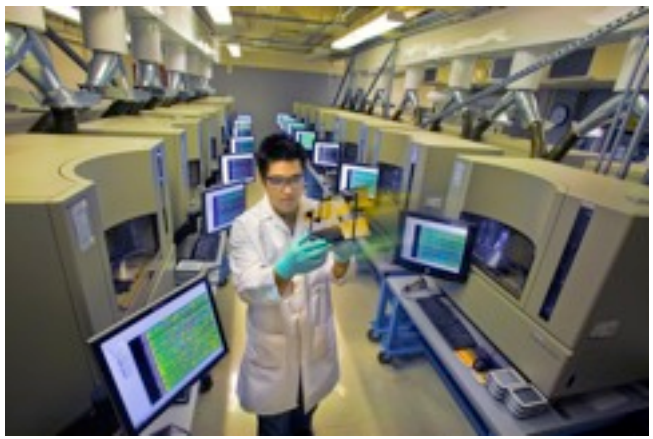

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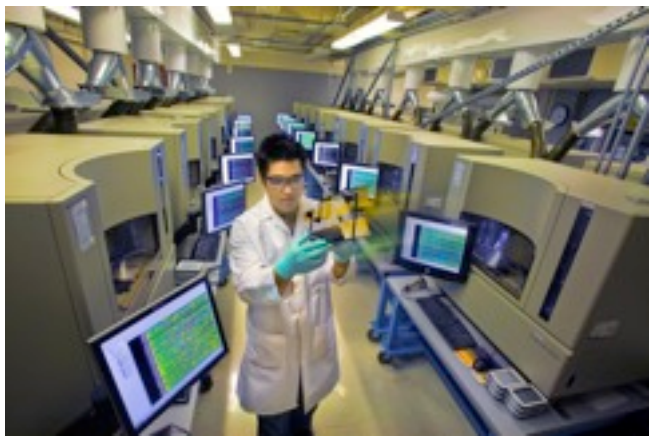

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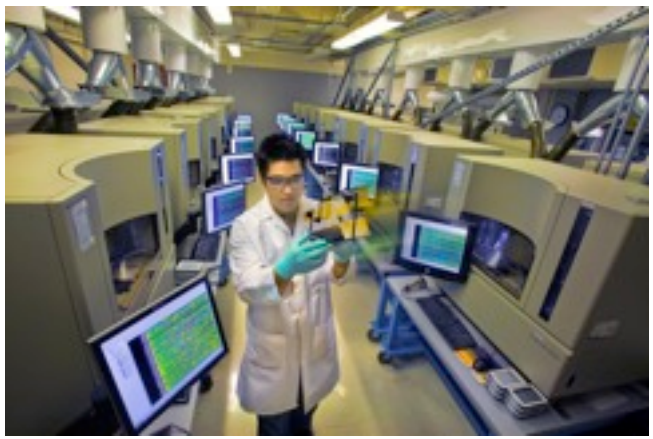
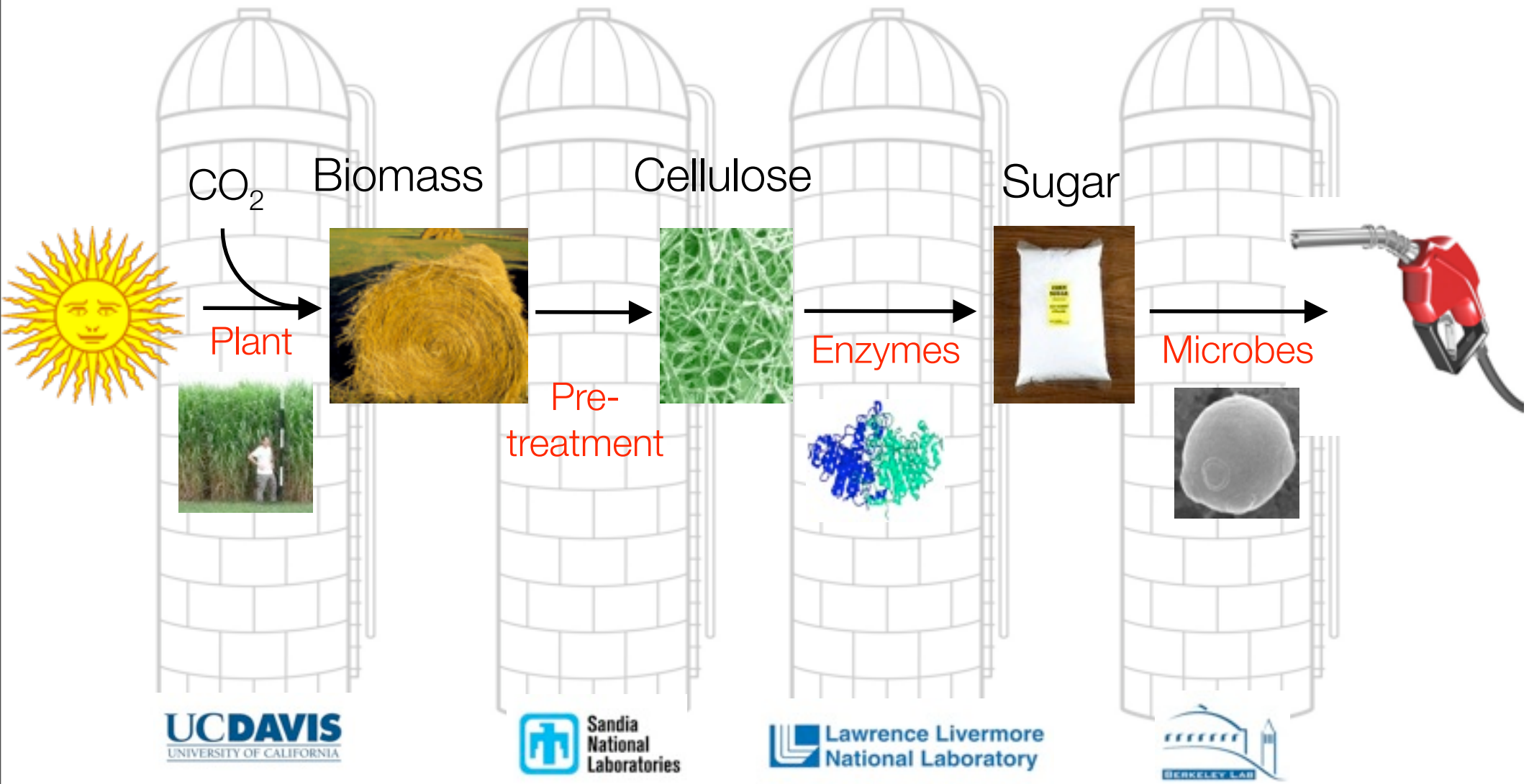


JBEI & DOE's Bioenergy Research Centers: The Next Model for DOE Initiatives



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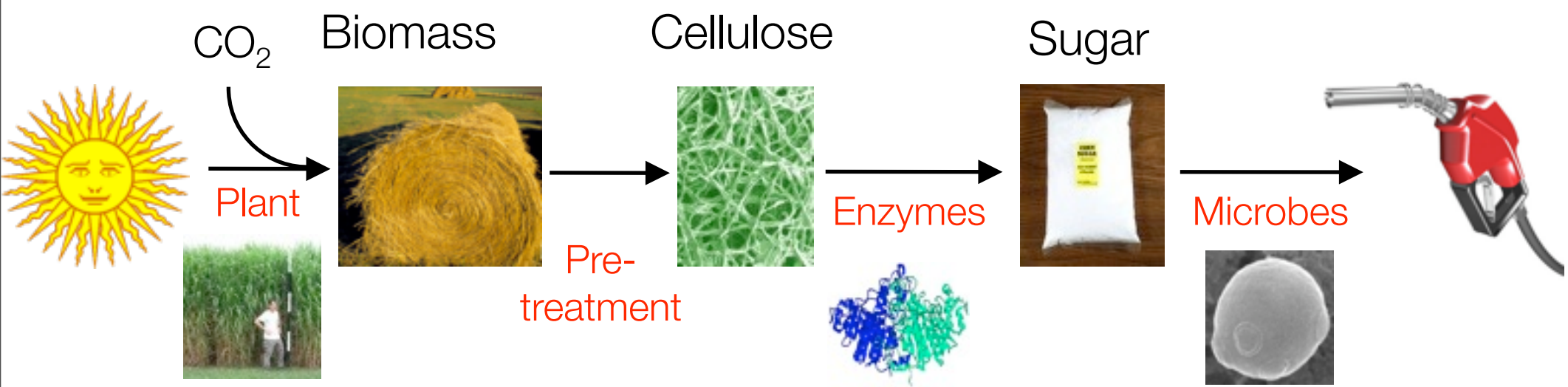
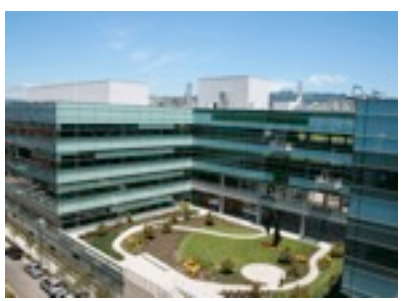


JBEI: a single location



Building on JBEI:
DOE's (Future) Advanced Biofuels Pilot Plant Facility

USER FACILITY FOR DOE BIOENERGY RESEARCH

- State-of-the-art scale-up facilities
- Translate research advances to commercial practice
- Provide quantitative information for design, construction and economic evaluation of new biofuels production processes
- Dedicated staffing and multi-year support
- $20M (EERE)

Capabilities for:

- **Enzyme production**
- **Biomass pretreatment**
- **Biofuels production**
- **Separation & purification**
- **Analytical chemistry & biology**

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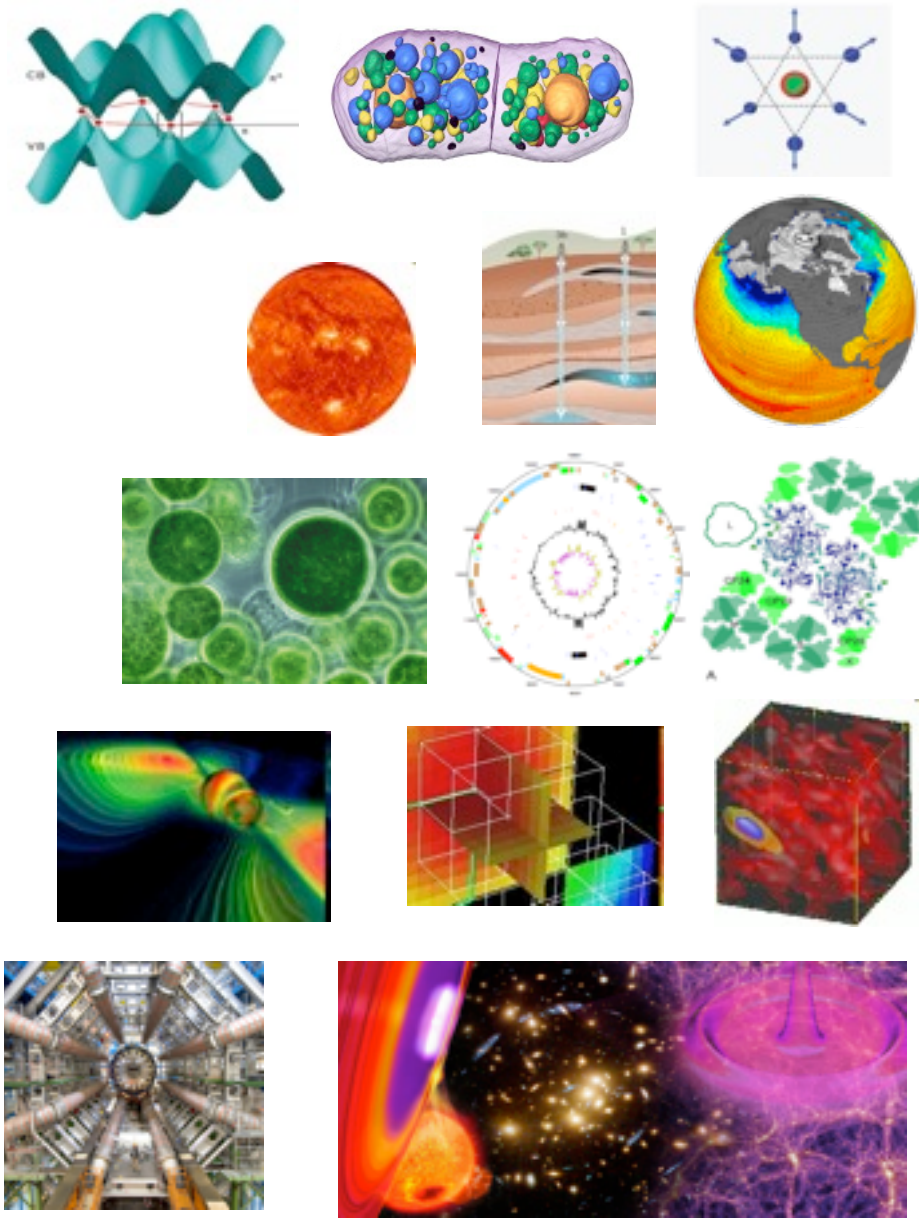
Biofuels model for research at LBNL: from basic to applied

Berkeley Lab's Priority Strategic Science Areas

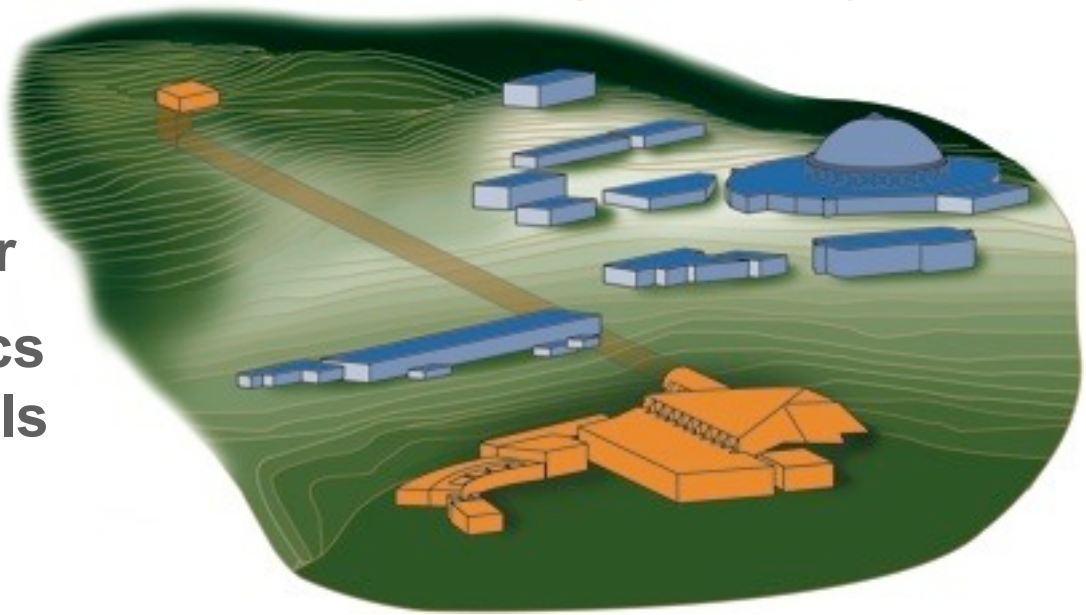
- **Soft X-Ray Science**
- **Energy and the Environment**
- **Life Sciences for Energy Research**
- **Computational Science**
- **High-Energy and Nuclear Physics**

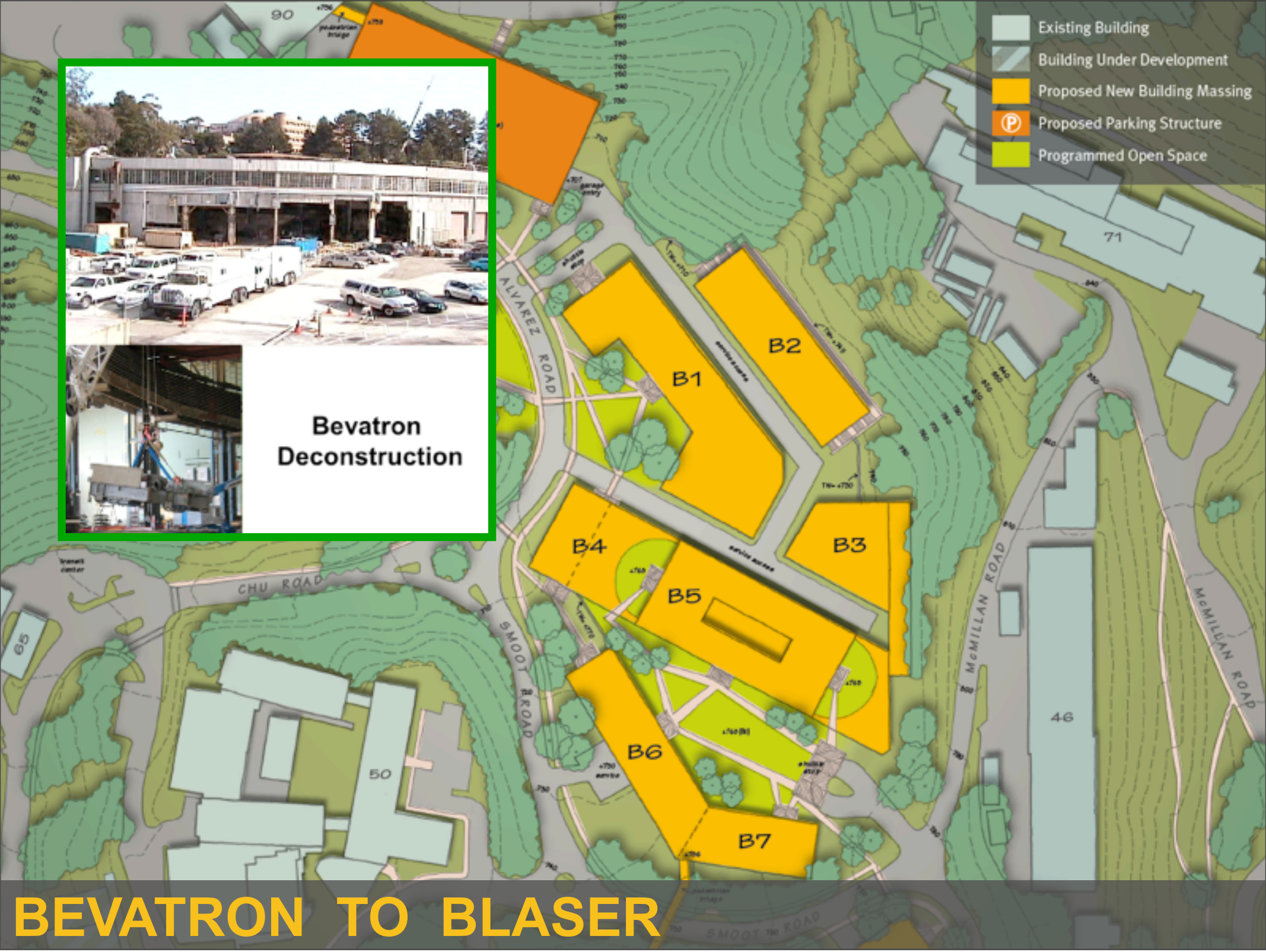


Soft X-Ray Science

- **Advanced Light Source Renewal**
  - **Beamline renewal and upgrades**
  - **Accelerator renewal to increase brightness**

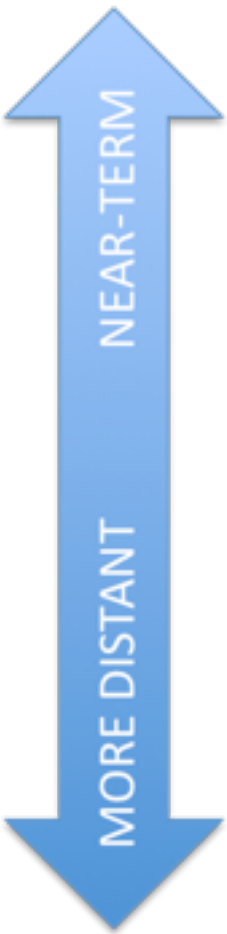
- **Berkeley Laser Array for Science and Engineering Research (BLASER)**
  - **Coherent soft x-ray laser**
  - **Reveal electron dynamics in reactions and materials**





BEVATRON TO BLASER

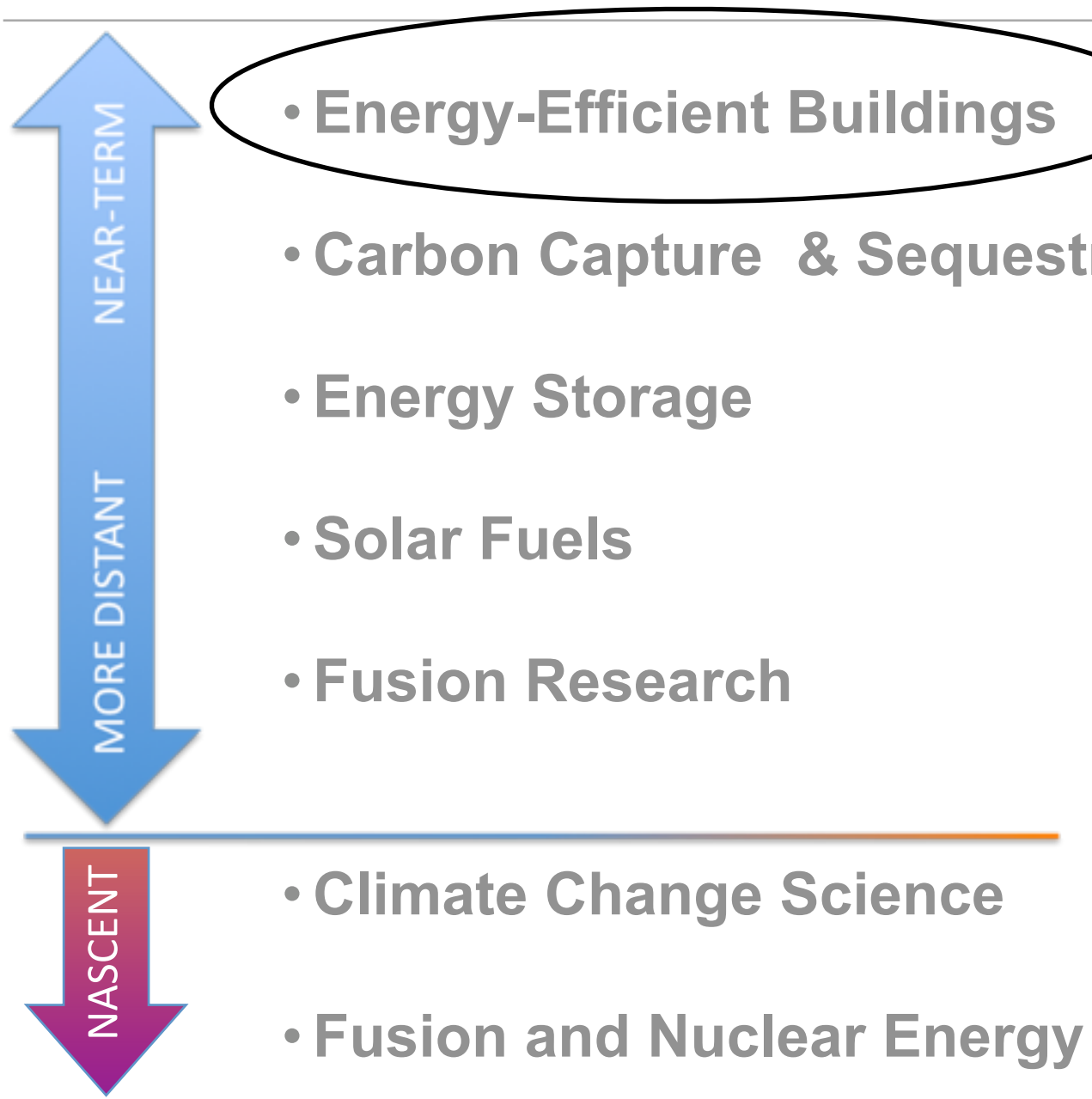
Energy and Environment: Berkeley Lab's Strategy



- **Energy-Efficient Buildings**
- **Carbon Capture & Sequestration**
- **Energy Storage**
- **Solar Fuels**
- **Fusion Research**

- **Climate Change Science**
- **Fusion and Nuclear Energy**

Energy and Environment: Berkeley Lab's Strategy



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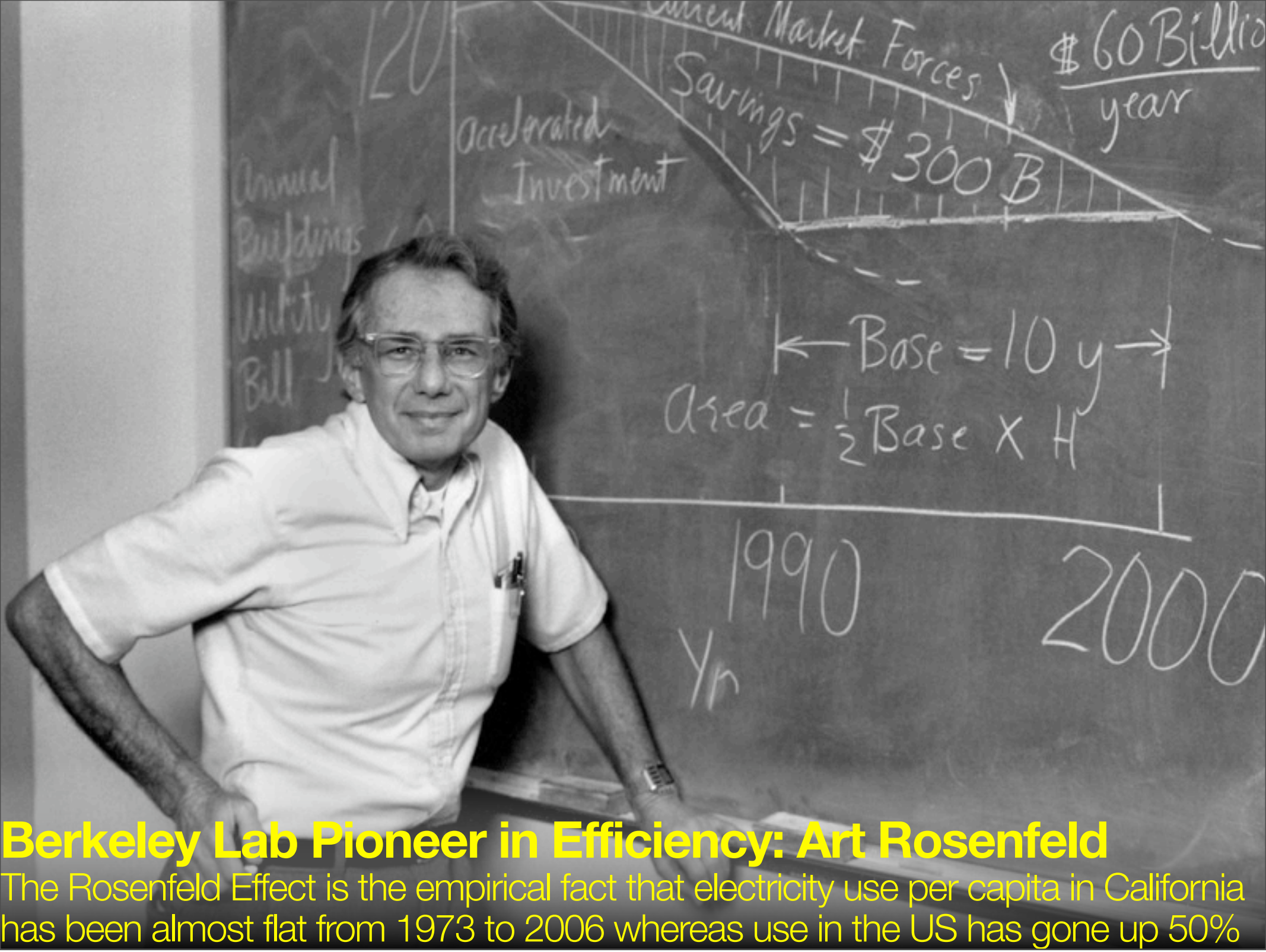
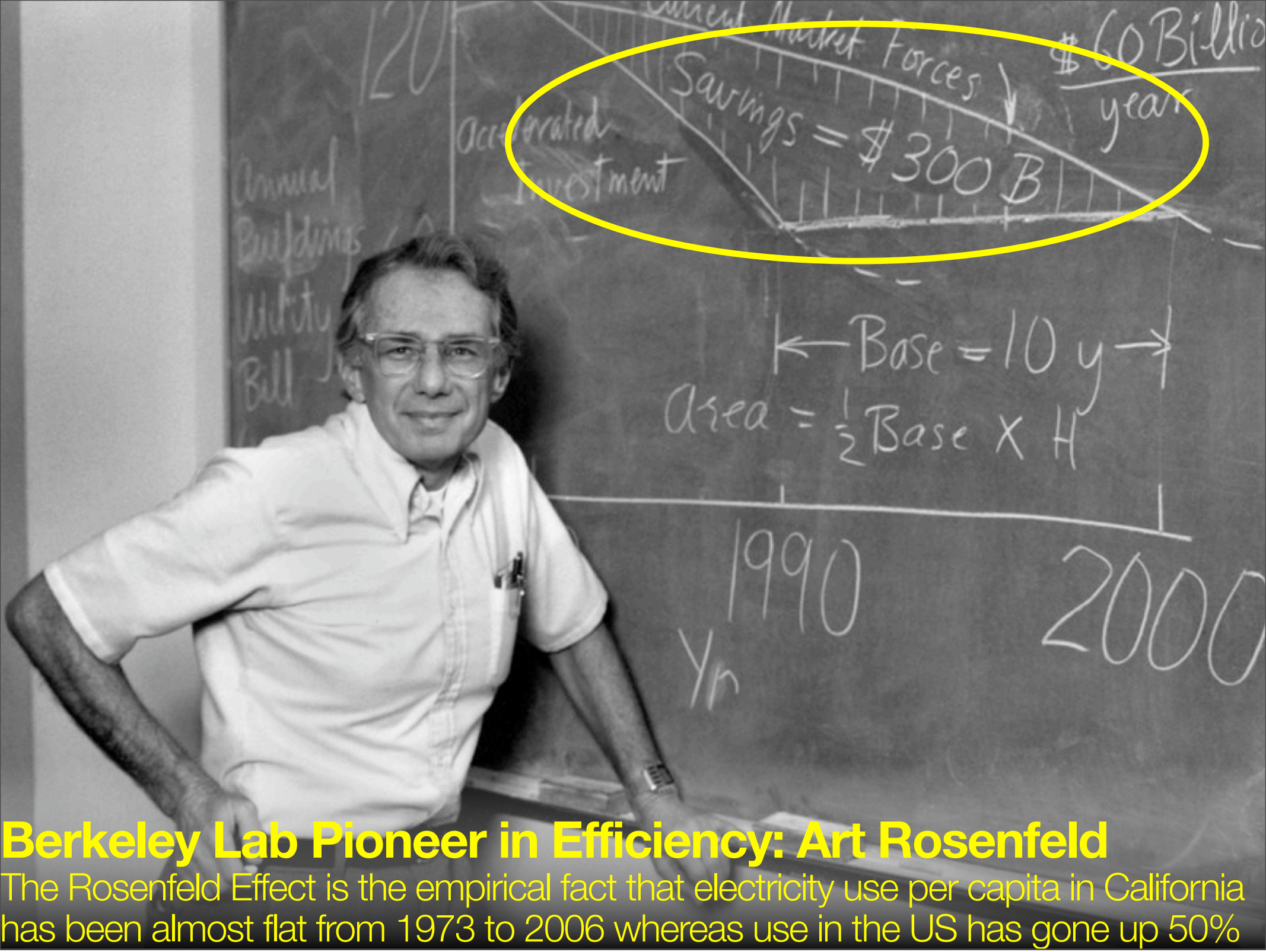


Berkeley Lab Pioneer in Efficiency: Art Rosenfeld

The Rosenfeld Effect is the empirical fact that electricity use per capita in California has been almost flat from 1973 to 2006 whereas use in the US has gone up 50%



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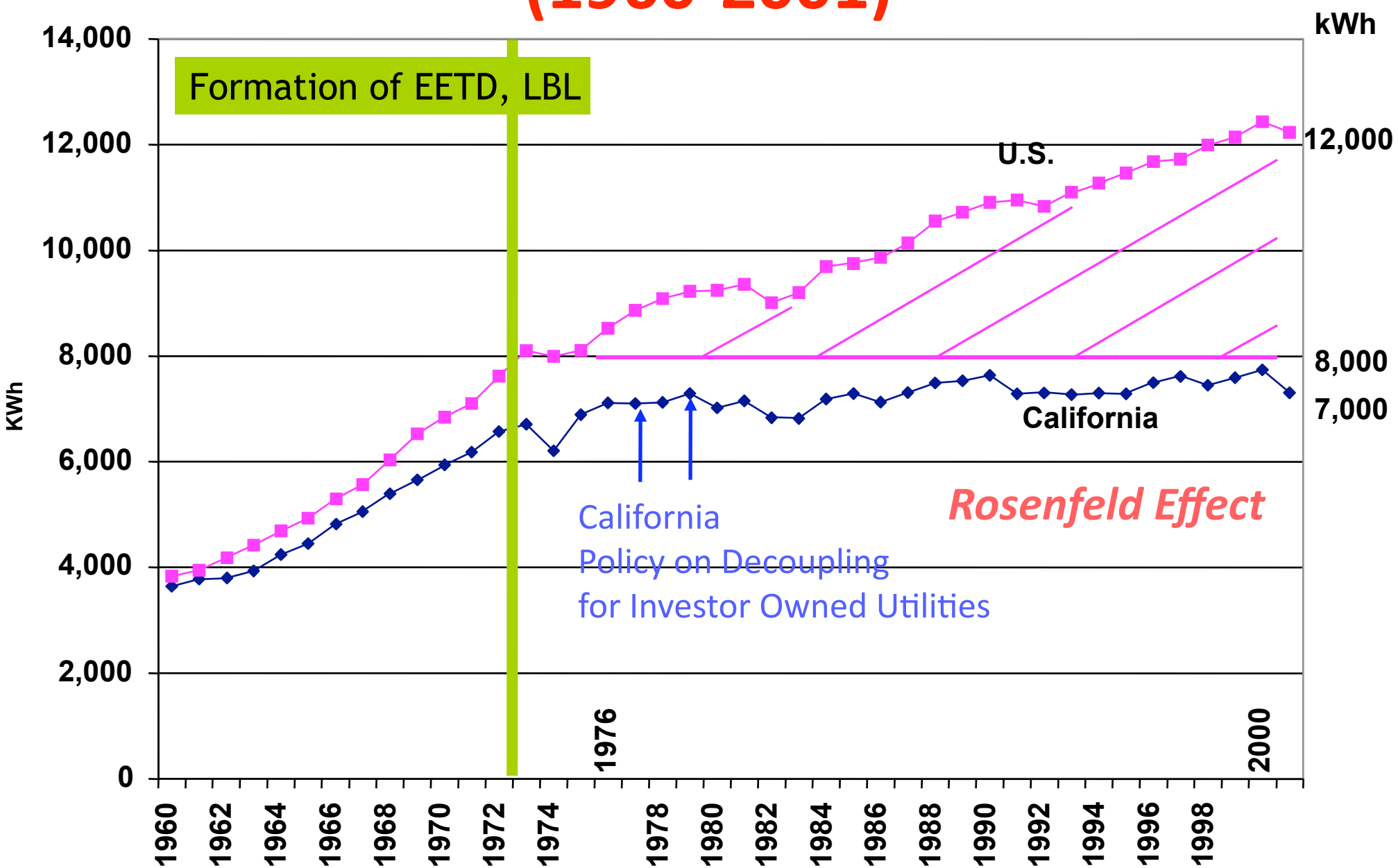
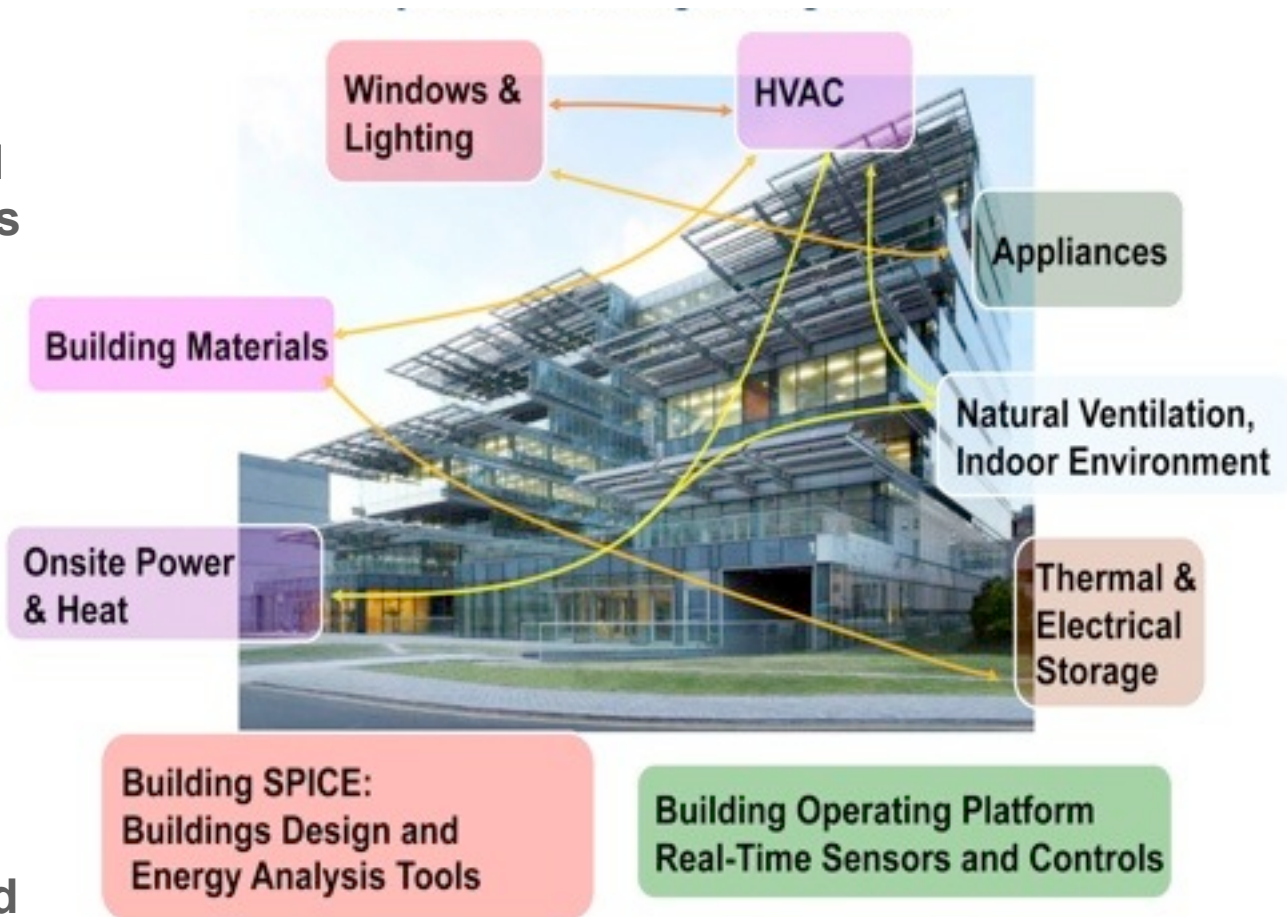
Per Capita Electricity in the U.S. and California (1960-2001)



Buildings Efficiency Hub

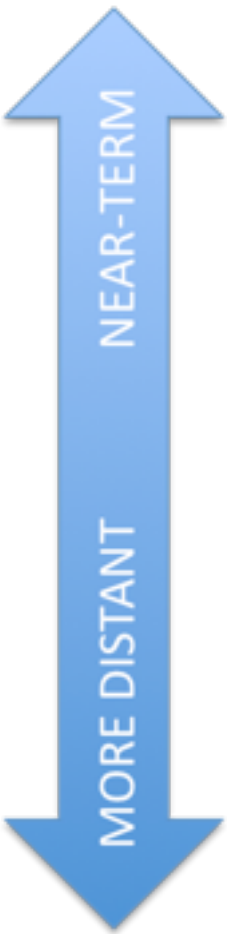
Research Areas:

- **Integrating systems: lighting, windows, HVAC, envelope, and other components/sub-systems**
- **Integrating processes: design, build, deliver, operate**
- **Measure, track and optimize performance by integrating sensors, communication, modeling/computation, control, and visualization**
- **Large scale computational modeling is critical**
- **Integrate testing, validation and commercialization**



Possible partnership with other labs, industries, and universities

Energy and Environment: Berkeley Lab's Strategy



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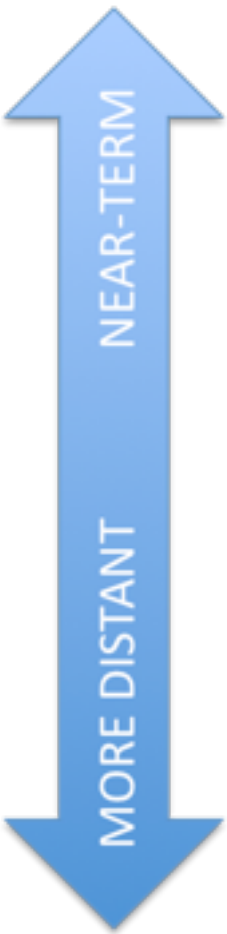

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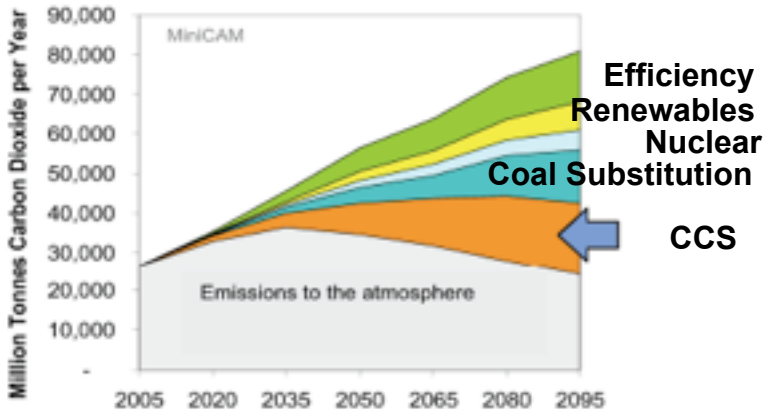
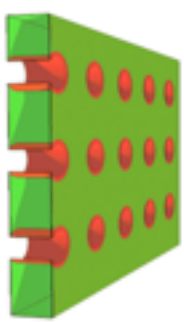
Carbon Capture and Sequestration

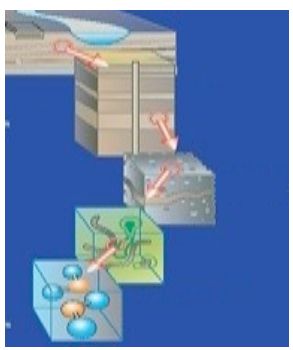
- **Carbon capture R&D: nanostructured membranes to remove CO_2 from flue gases or air: UCB EFRC**
- **Geological sequestration: integrated hydrological, geochemical, and geophysical R&D: LBNL EFRC**
- **Bio-enhanced sequestration through plant and microbial processes**
- **Possible collaboration with Stanford, PNNL, UT Austin…**





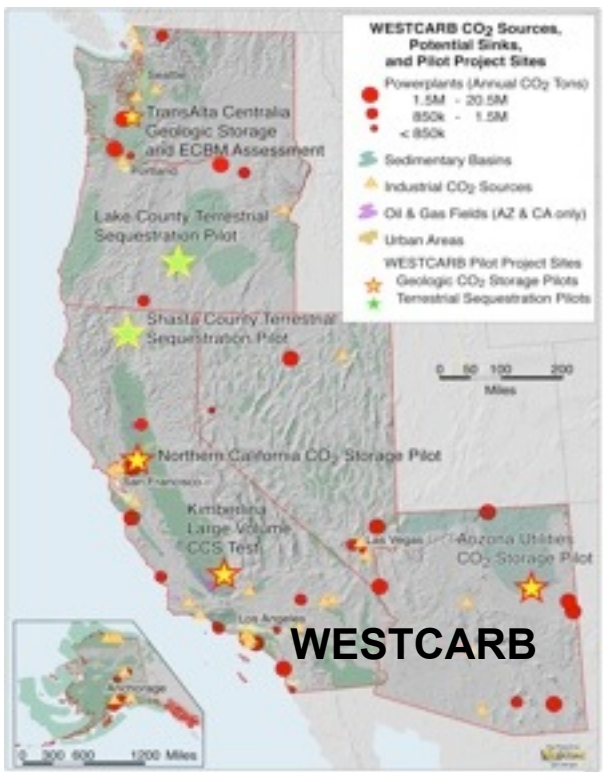
Engineered

Microbial

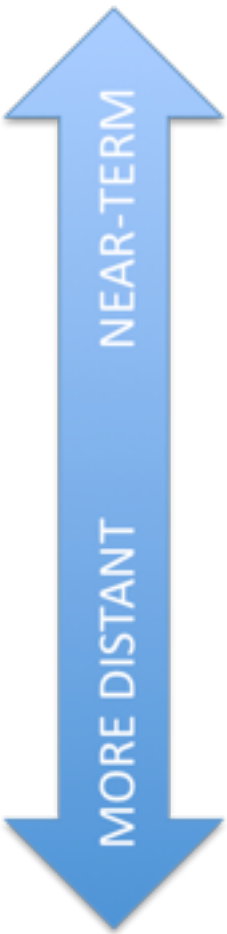


Multiscale

Field



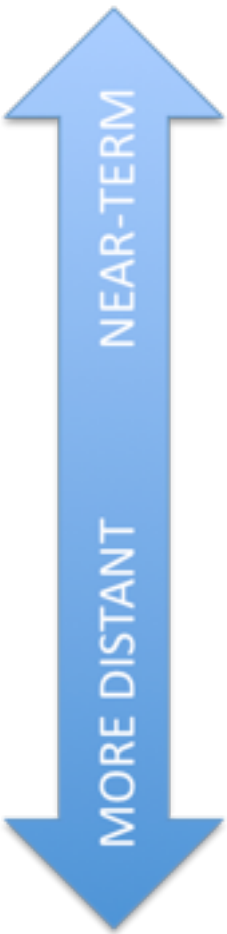
Energy and Environment: Berkeley Lab's Strategy



- **Energy-Efficient Buildings**
- **Carbon Capture & Sequestration**
- **Energy Storage**
- **Solar Fuels**
- **Fusion Research**

- **Climate Change Science**
- **Fusion and Nuclear Energy**

Energy and Environment: Berkeley Lab's Strategy

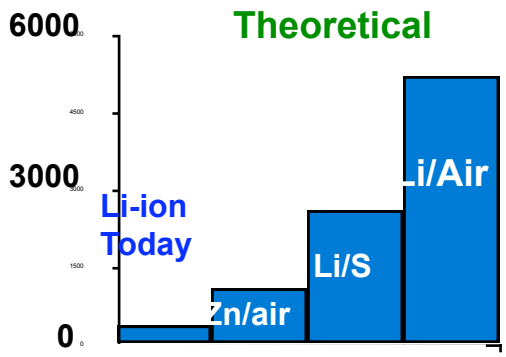


- Energy-Efficient Buildings
- Carbon Capture & Sequestration
- Energy Storage
- Solar Fuels
- Fusion Research

- Climate Change Science
- Fusion and Nuclear Energy

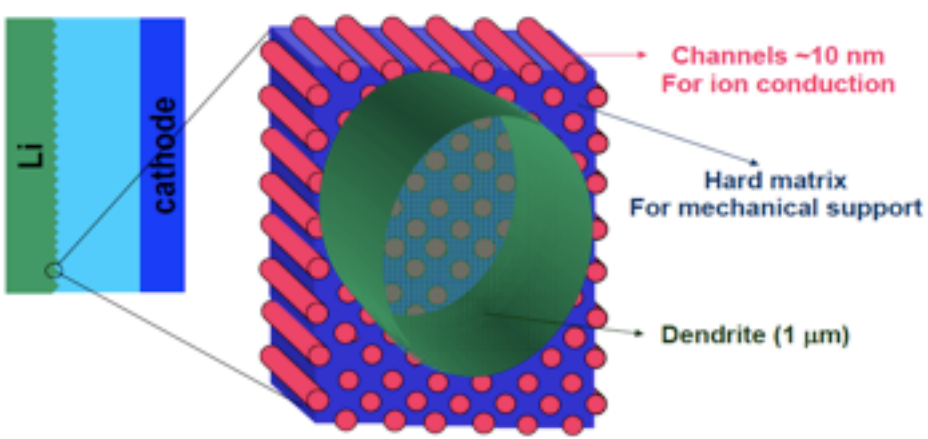
Energy Storage

- Science and technology drivers
  - Far from efficiency limits
  - New chemistries and materials
- Possible collaboration with Argonne

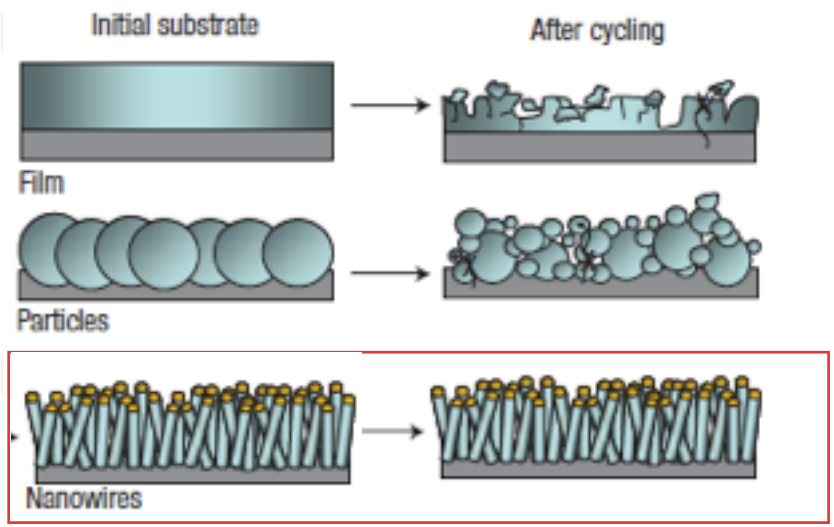


- Nanotechnology-enabled anodes, cathodes, and transport media have the potential to revolutionize battery technology

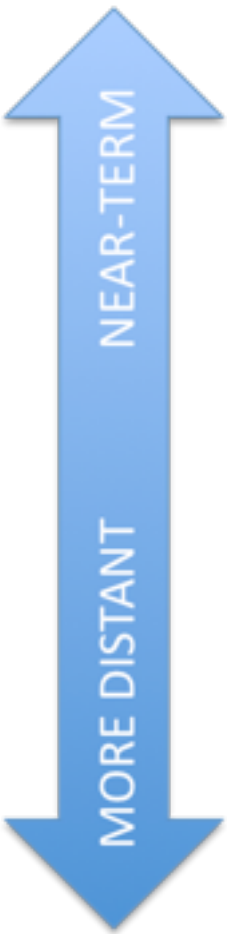
Block co-polymer Transport Media



Nanowire Anode



Energy and Environment: Berkeley Lab's Strategy



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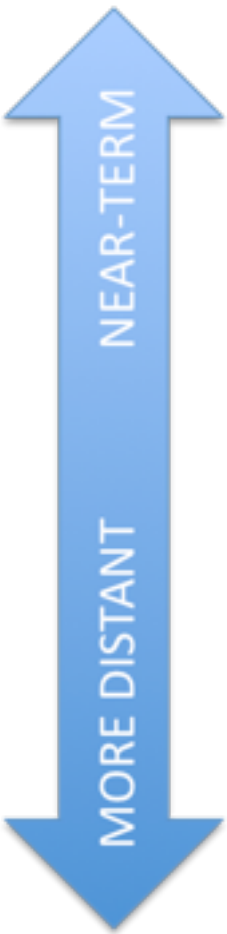

- Energy-Efficient Buildings
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- Fusion Research

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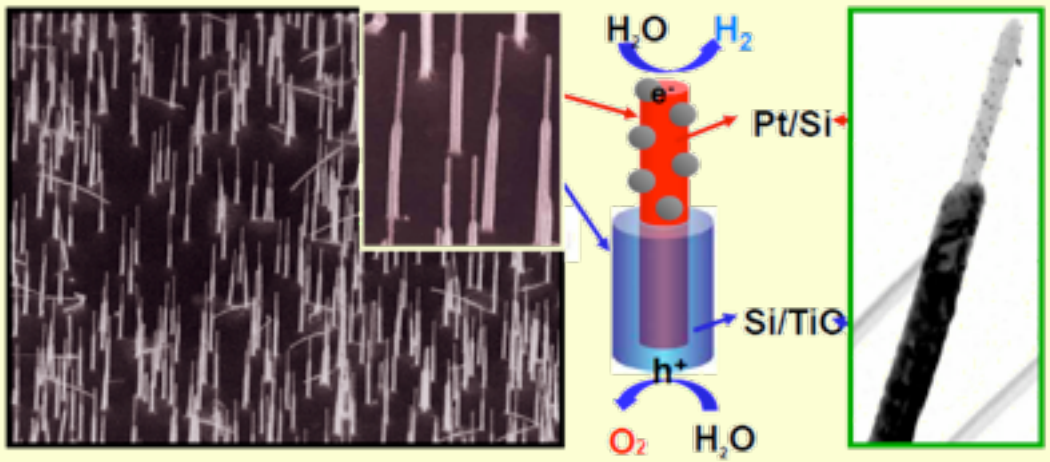
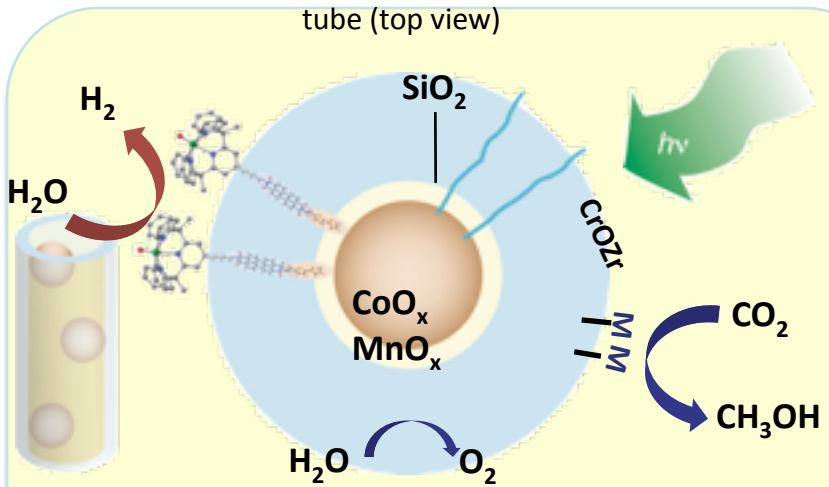
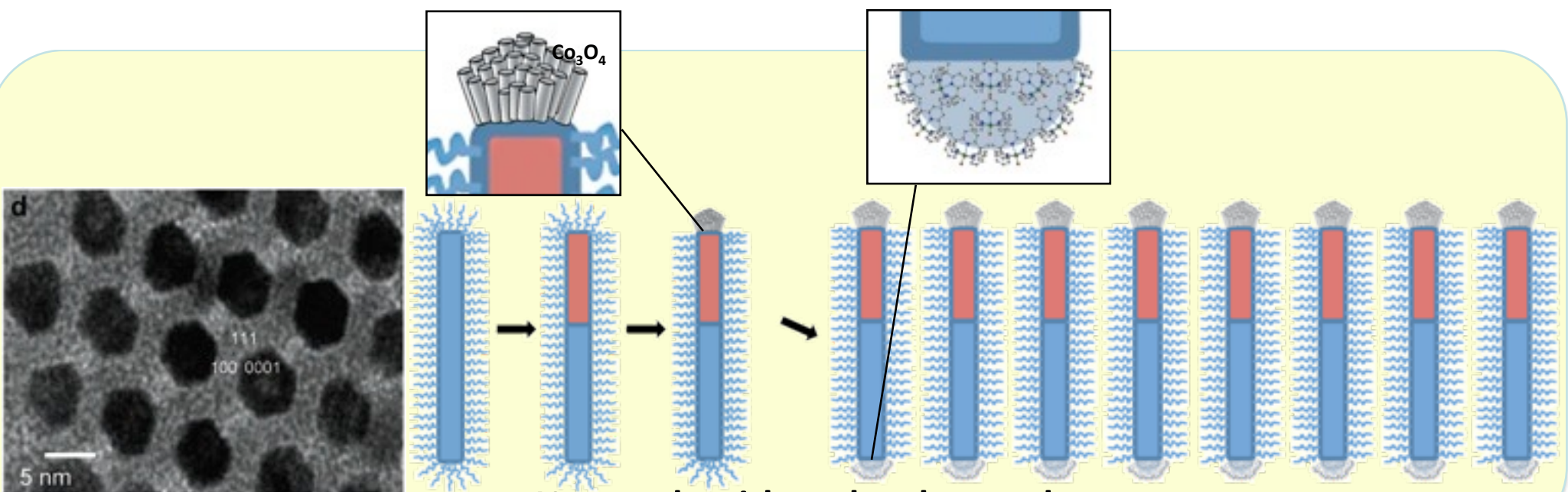
Helios SERC : Three prototypes of artificial photosynthetic units



Forest of concentric cylindrical nanotubes



Catalyst-in-tube design with solid- state catalyst



Nanorods with molecular catalysts

Fuels from Sunlight: Helios Research Institute

- A Partnership to accelerate the development and distribution of transportation fuel derived from carbon dioxide and water using chemistry powered by sunlight

- 2 Sites:
  Northern California, near UCB-LBNL
  Southern California, near Caltech

- Goals:
  Low-cost and abundant materials optimized for light collection and product separation
  Self-assembly processes for scalable manufacture

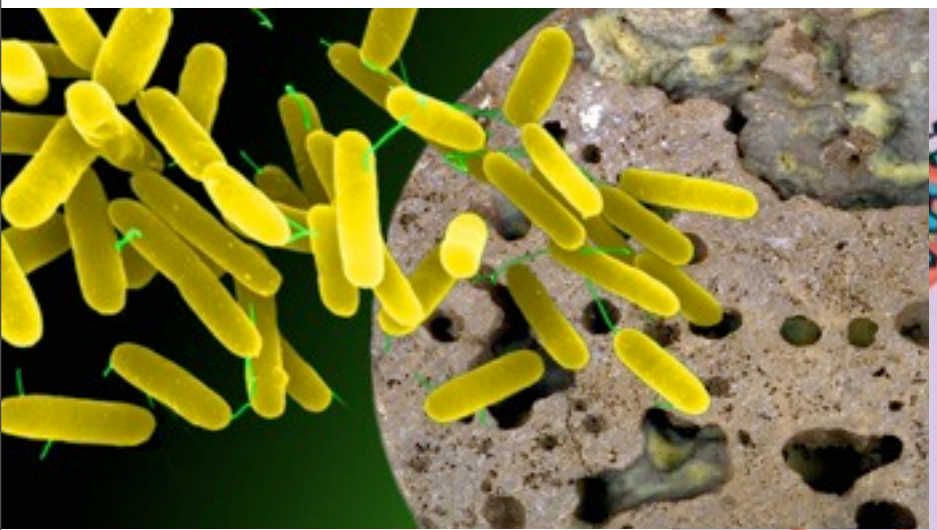
- Catalysts for new energy storage chemistries

Old Town

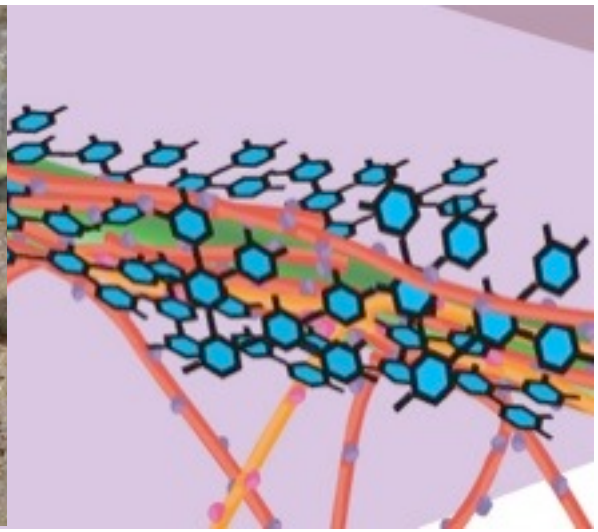
Existing Building
Proposed New Building Massing
2001 Study Massing (Perkins Design Associates)
Programmed Open Space

OLD TOWN TO GREEN TOWN

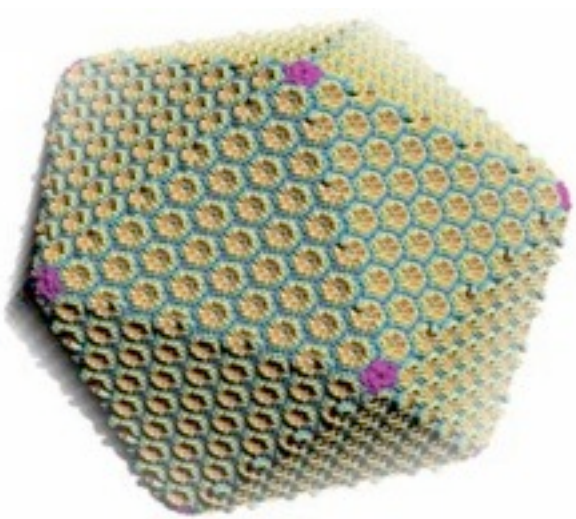
Life Sciences for Energy Research



remediation



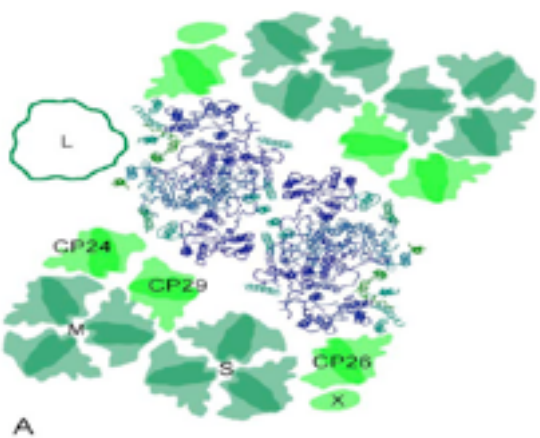
biofuels

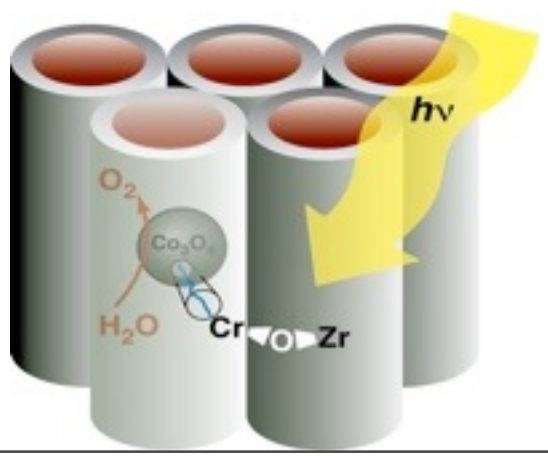


biomaterials

low dose rad.

evolved and engineered photosynthesis

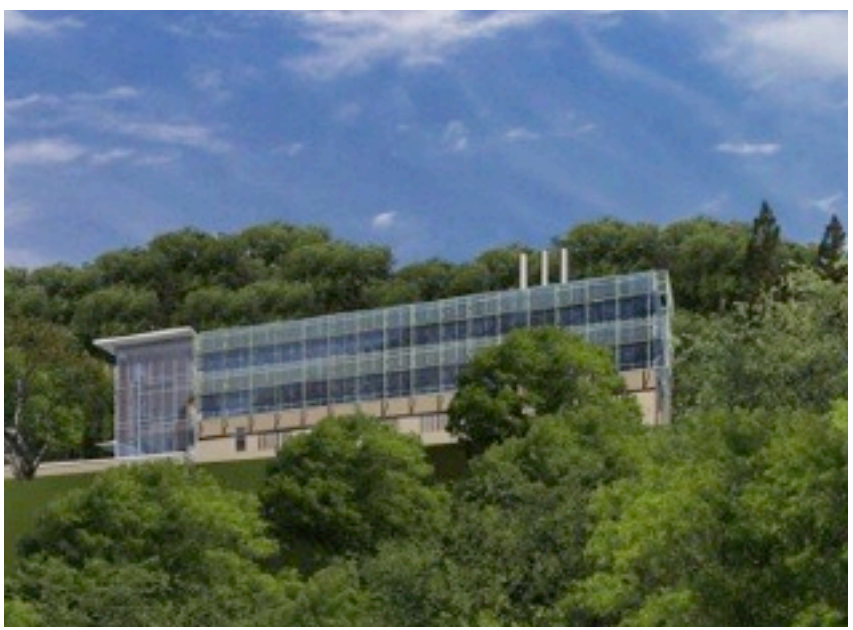




Infrastructure Projects Relevant to Life Sciences

Potter Street

Building 74 Seismic retrofit and renovation(2011)

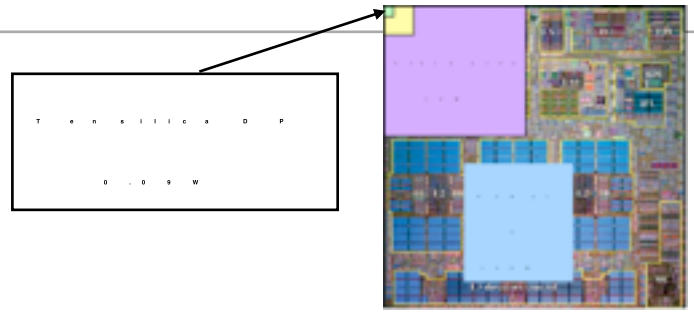


SLI General Purpose Laboratory (2012)

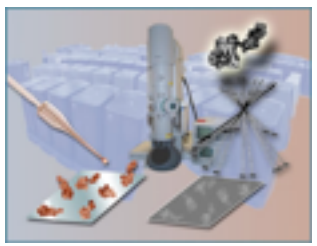
Offsite Biocampus?

Extreme Scale Computational Science

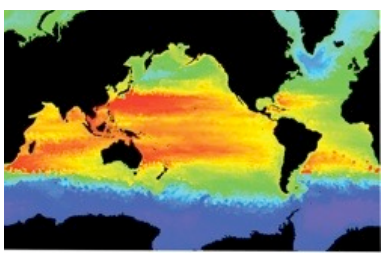
- **Energy-Efficient Computing at the Extreme Scale**

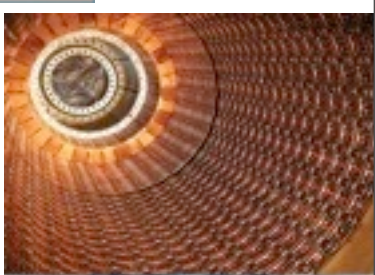


- **Leadership Data Facility**

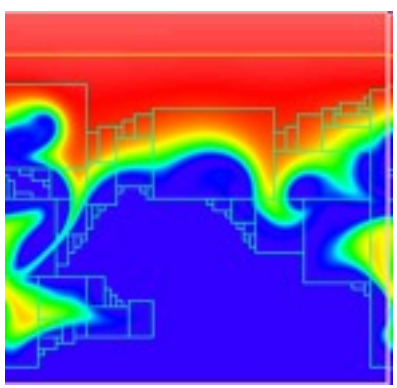


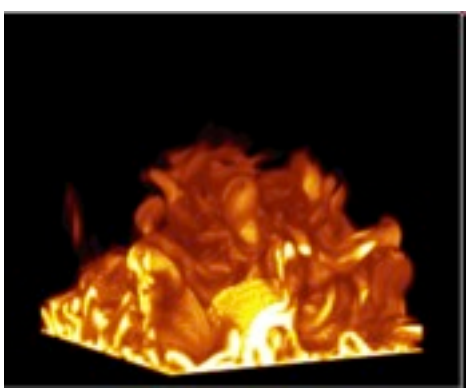
- **Terabit Networking for Distributed Science**





- **Mathematics and Modeling for Energy Challenges**





Solar Technology Evolution

Solar Thermal:

Harness heat

Steam engine

~25 meV

Single Gap Photovoltaic:

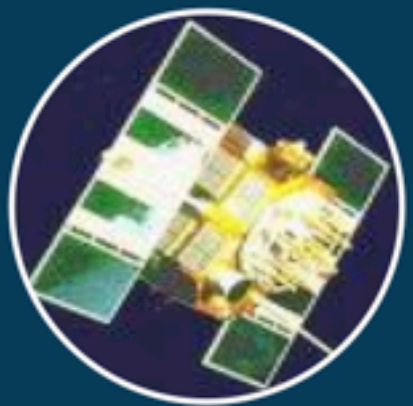
Silicon and Thin Film

~1eV

Photoelectric effect

Up to 24% efficiency

$4-5/W



Multigap cells:

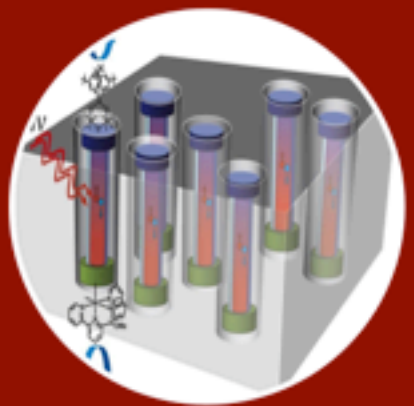
Semiconductor processing

Artificial materials

~Up to 40% efficiency

$350-1000s$/W

Concentration?



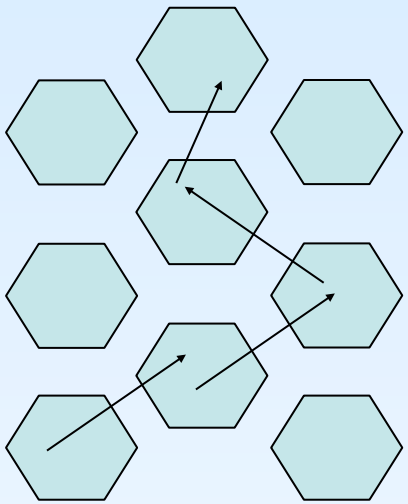
Solar Fuel:

Artificial Photosynthesis

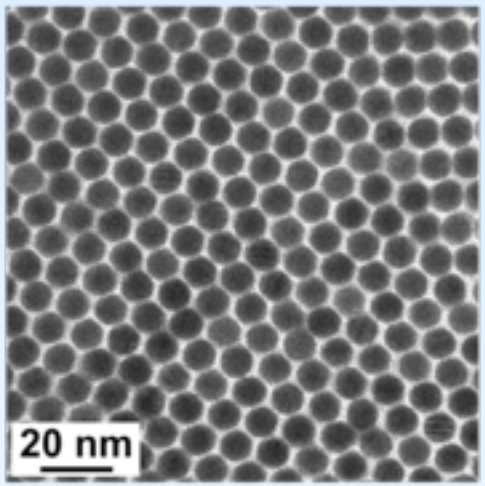
Enabled by nanomaterials

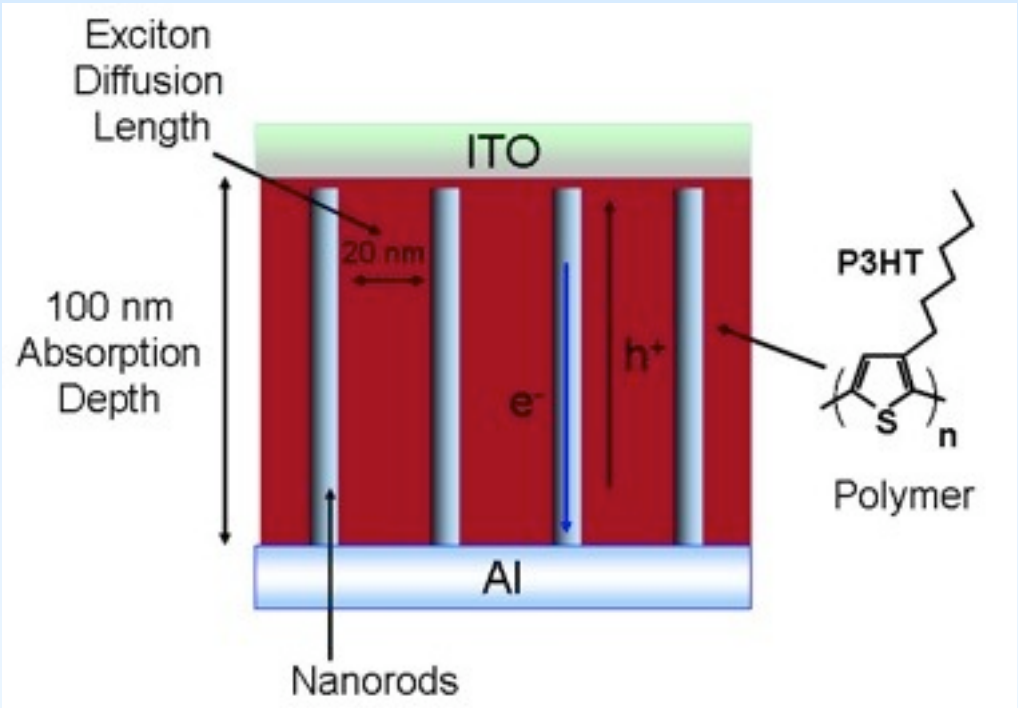
climbing the thermodynamic ladder

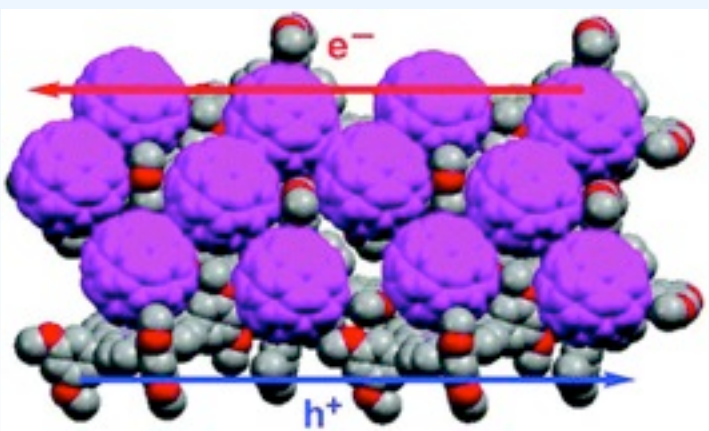
Some designs of nanotechnology enabled solar cells



dots





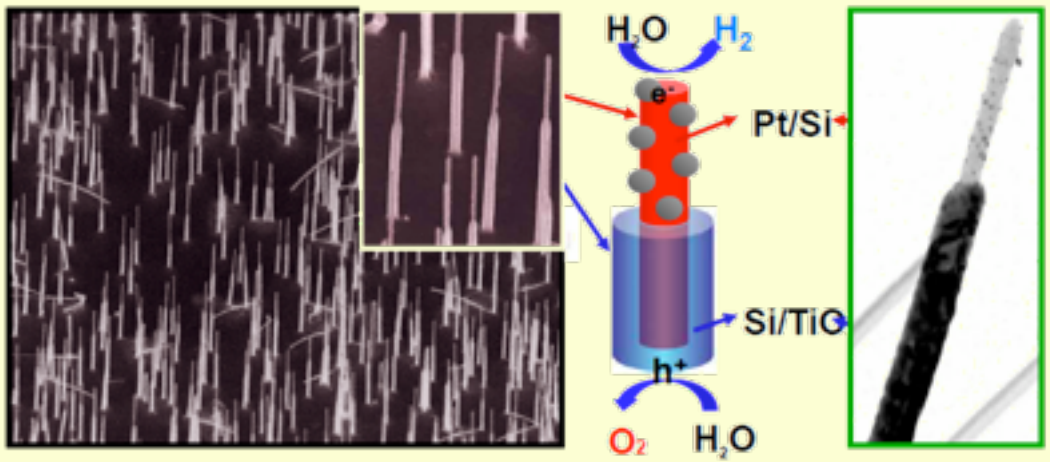


Polymers/organic

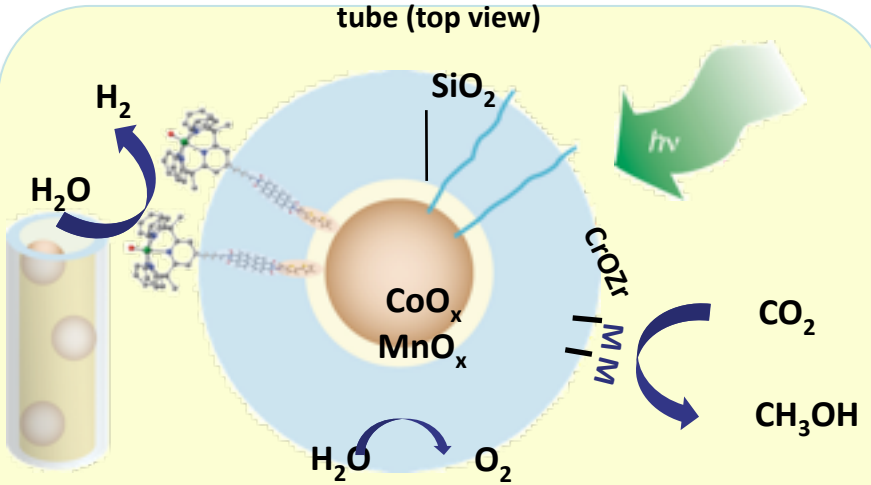
Simultaneously must control:

- **Light absorption**
- **Charge separation**
- **Charge transport/collection**
- **Use minimum amount of material**
- ***Really cheap, scalable process***

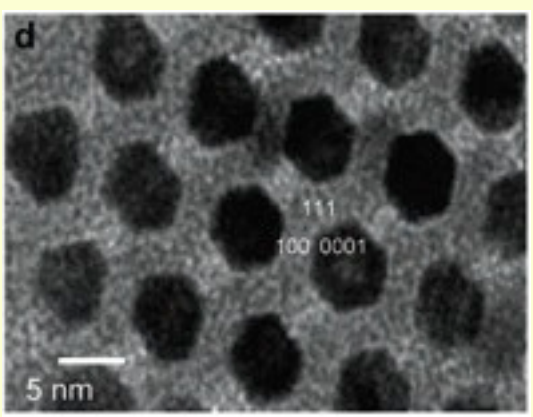
Helios SERC : Three prototypes of integrated fuel generating systems under development

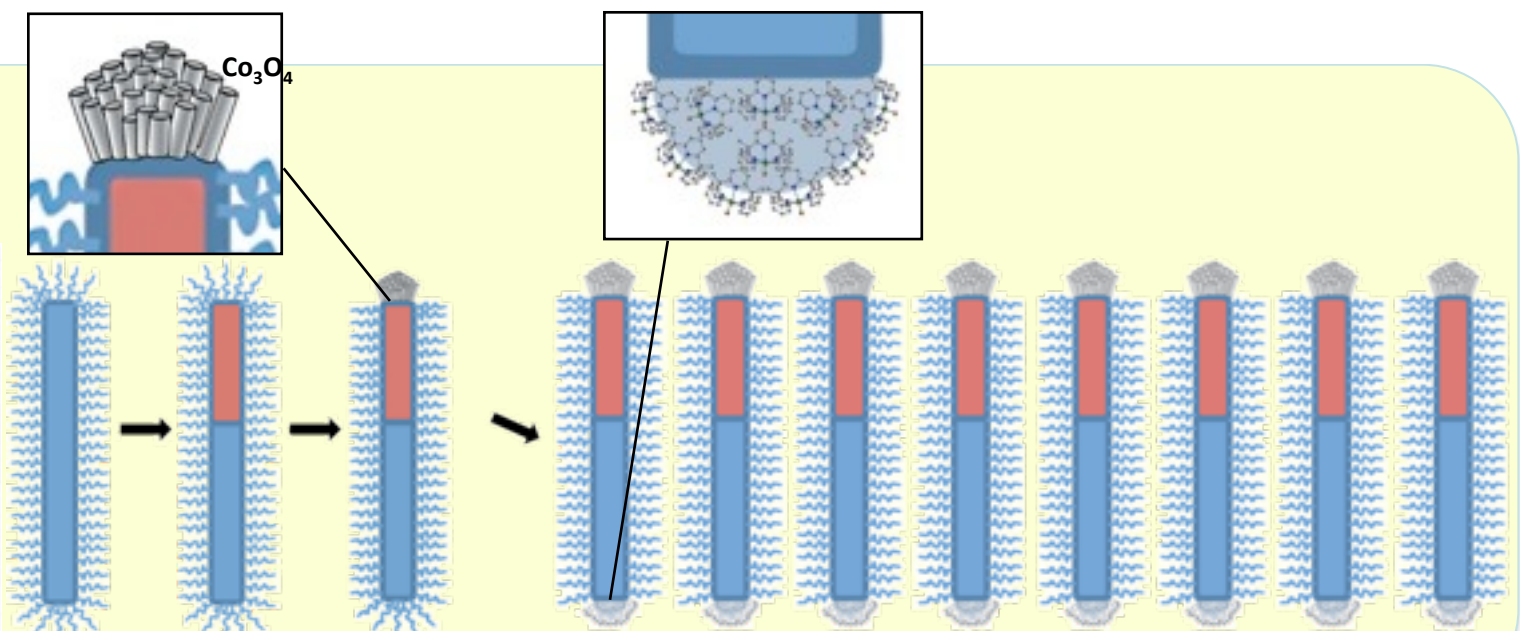


Forest of concentric cylindrical nanotubes



Catalyst-in-tube design with solid- state catalyst

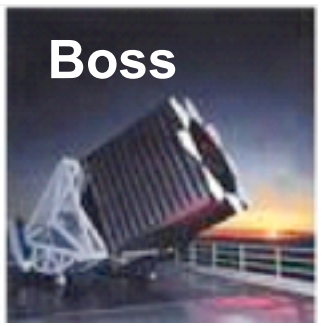


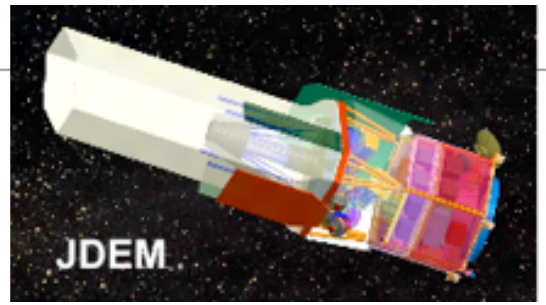


Nanorods with molecular catalysts

High Energy and Nuclear Physics

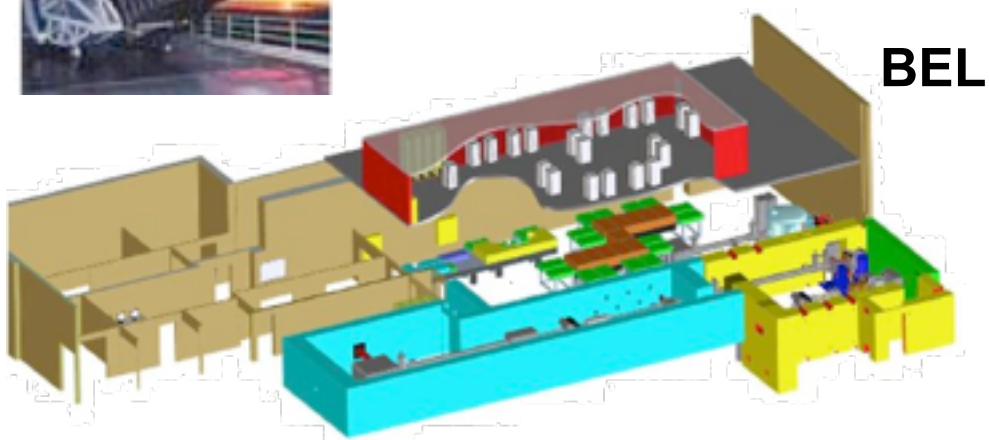
- **Dark Energy Research**
  - **Joint Dark Energy Mission**
  - **Boss and Big Boss**





- **Optical Accelerators**
  - **ARRA funding**

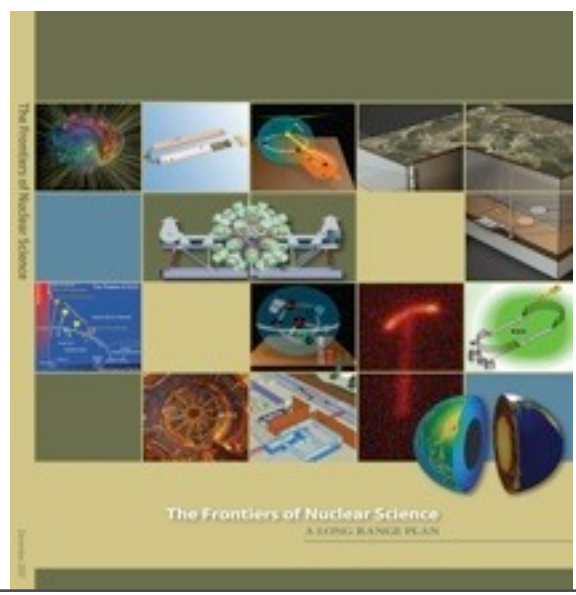
BELLA

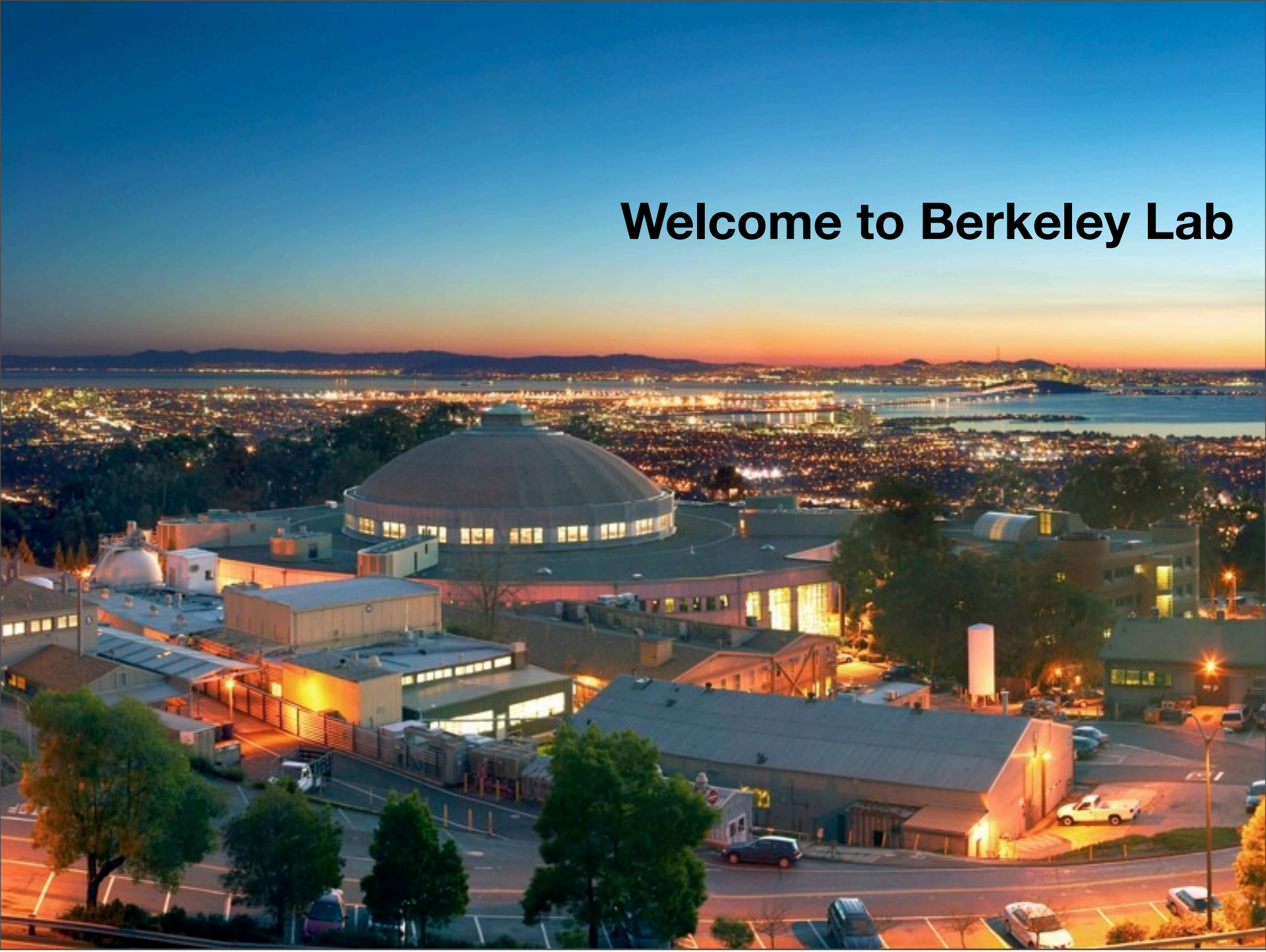


- **Nuclear Physics Frontiers**

- **Science enabled by the Deep Underground Science and**

Nuclear Physics Long Range Plan




Welcome to Berkeley Lab